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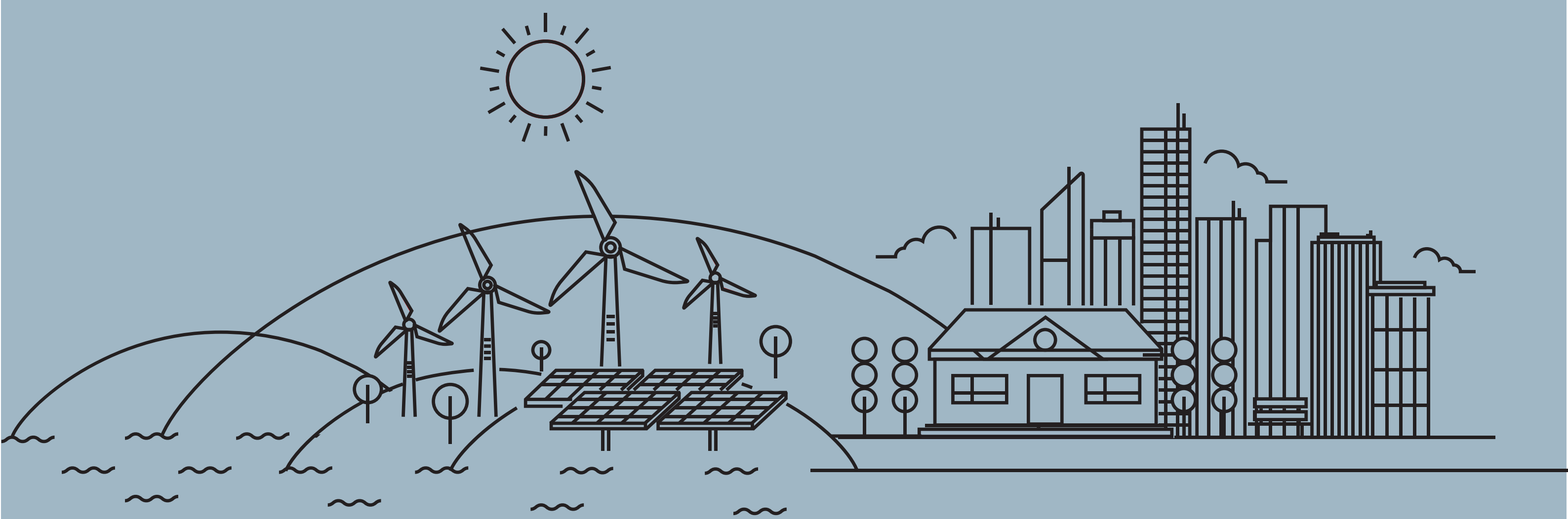

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- Brazilian Association of Photovoltaic Solar Energy
- Brazilian Biogas Association
- Brazilian Mineral Coal Association
- Association of Biofuel Producers
- National Bank for Economic and Social Development
- Caixa
- Management and Strategic Studies Center
- Centro de Inteligência Territorial
- Environmental Company of the State of São Paulo
- Companhia Siderúrgica Pecem
- Confederation of Agriculture and Livestock of Brazil
- National Confederation of Industry
- National Transport Confederation
- Brazilian Agricultural Research Corporation
- Energy Research Company
- F2Brasil S/A
- Financier of Studies and Projects
- Getúlio Vargas Foundation
- GreenAnt Ltda
- Instituto Aço Brasil
- Amazon Conservation and Sustainable Development Institute
- Amazon Environmental Research Institute
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- National Institute of Technology
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List of Abbreviations and Acronyms

ABAL –	Associação Brasileira do Alumínio / Brazilian Aluminum Association
ABCB –	Associação Brasileira dos Criadores de Bovinos / Brazilian Cattle Breeders Association
ABCCAN –	Associação Brasileira de Criadores de Canchim / Brazilian Canchim Breeders Association
ABCM –	Associação Brasileira do Carvão Mineral / Brazilian Coal Association
ABCP –	Associação Brasileira de Cimento Portland / Brazilian Portland Cement Association
ABCZ –	Associação Brasileira dos Criadores de Zebu / Brazilian Zebu Breeders Association
ABDI –	Agência Brasileira de Desenvolvimento Industrial / Brazilian Industrial Development Agency
Abema –	Associação Brasileira de Entidades Estaduais de Meio Ambiente / Brazilian Association of State Environmental Entities
Abimaq –	Associação Brasileira de Indústria de Máquinas e Equipamentos / Brazilian Machinery and Equipment Industry Association
Abinee –	Associação Brasileira da Indústria Elétrica e Eletrônica / Brazilian Electrical and Electronics Industry Association
Abiogás –	Associação Brasileira do Biogás / Brazilian Biogas Association
Abiquim –	Associação Brasileira da Indústria Química / Brazilian Chemical Industry Association
Abividro –	Associação Brasileira das Indústrias de Vidro / Brazilian Association of Glass Industries
ABNT –	Associação Brasileira de Normas Técnica / Brazilian Technical Standards Association
ABSOLAR –	Associação Brasileira da Energia Solar Fotovoltaica / Brazilian Photovoltaic Solar Energy Association
AEB –	Agência Espacial Brasileira / Brazilian Space Agency
Afolu –	Agriculture, forestry and other land use
AFS –	Agroforestry System
ANA –	Agência Nacional de Águas / National Water Agency
Anamma –	Associação Nacional de Órgãos Municipais de Meio Ambiente / National Association of Municipal Environmental Bodies
Anatel –	Agência Nacional de Telecomunicações / National Telecommunications Agency
ANCP –	Associação Nacional de Criadores e Pesquisadores / National Association of Breeders and Researchers
Aneel –	Agência Nacional de Energia Elétrica / National Electric Energy Agency
Anfavea –	Associação Nacional dos Fabricantes de Veículos Automotores / National Association of Motor Vehicle Manufacturers
ANP –	Agência Nacional de Petróleo, Gás Natural e Biocombustíveis / National Petroleum, Natural Gas and Biofuels Agency
APROBIO –	Associação dos Produtores de Biocombustíveis / Association of Biofuel Producers
Asbraap –	Associação Brasileira de Agricultura de Precisão / Brazilian Precision Agriculture Association
Assocon –	Associação Nacional da Pecuária Intensiva / National Intensive Livestock Farming Association
Ater –	Assistência técnica e extensão rural / Technical assistance and rural extension

BNDES –	Banco Nacional de Desenvolvimento Econômico e Social / National Bank for Economic and Social Development
Câmara I4.0 –	Câmara Brasileira da Indústria 4.0 / Brazilian Chamber of Industry 4.0
Capes –	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior / Coordination for the Improvement of Higher Education Personnel
Capex –	Capital expenditure
CBAP –	Comissão Brasileira de Agricultura de Precisão / Brazilian Commission for Precision Agriculture
CBAPD –	Comissão Brasileira de Agricultura de Precisão e Digital / Brazilian Commission for Precision and Digital Agriculture
CBIC –	Câmara Brasileira da Indústria da Construção / Brazilian Construction Industry Chamber
Cenpes –	Centro de Pesquisas Leopoldo Américo Miguez de Mello / Leopoldo Américo Miguez de Mello Research Center
Censipam –	Centro Gestor e Operacional do Sistema de Proteção da Amazônia / Management and Operational Center for the Amazon Protection System
Cepea –	Centro de Estudos Avançados em Economia Aplicada / Center for Advanced Studies in Applied Economics
Cepel –	Centro de Pesquisas de Energia Elétrica / Electric Energy Research Center
Ceplac –	Comissão Executiva do Plano da Lavoura Cacaueira/MMA / Executive Commission of the Cocoa Crop Plan / Ministry of Environment
Cerne –	Centro de Estratégias em Recursos Naturais e Energia / Center for Natural Resources and Energy Strategies
Cetem –	Centro de Tecnologia Mineral / Mineral Technology Center
Cetesb –	Companhia Ambiental do Estado de São Paulo / Environmental Company of the State of São Paulo
CGEE	Centro de Gestão e Estudos Estratégicos / Management and Strategic Studies Center
Chesf –	Companhia Hidroelétrica do São Francisco / São Francisco Hydroelectric Company
CIBiogás –	Centro Internacional de Energias Renováveis / International Renewable Energy Center
CNA –	Confederação da Agricultura e Pecuária do Brasil / Brazilian Agriculture and Livestock Confederation
CNI –	Confederação Nacional da Indústria / National Confederation of Industry
CNM –	Confederação Nacional dos Municípios / National Confederation of Municipalities
CNPq –	Conselho Nacional de Desenvolvimento Científico e Tecnológico / National Council for Scientific and Technological Development
CNT –	Confederação Nacional dos Transportes / National Transport Confederation
Contag –	Confederação Nacional dos Trabalhadores da Agricultura e Pecuária do Brasil / National Confederation of Agriculture and Livestock Workers of Brazil
Coppe/UFRJ –	Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa em Engenharia da Universidade Federal do Rio de Janeiro / Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering of the Federal University of Rio de Janeiro

CPFL – Companhia Paulista de Força e Luz / São Paulo Electricity Company (private sector utility company)
CPqD – Centro de Pesquisa e Desenvolvimento em Telecomunicações / Telecommunications Research and Development Center
CPRM – Serviço Geológico do Brasil / Geological Survey of Brazil
CREA – Conselho Regional de Engenharia e Agronomia / Regional Council of Engineering and Agronomy
CTIBC – Comitê Técnico da Indústria de Low Carbono / Low Carbon Industry Technical Committee
DBH – Diameter at breast height
DSG/EB – Diretoria do Serviço Geográfico do Exército Brasileiro / Directorate of the Geographical Service of the Brazilian Army
EIA – Environmental Impact Assessment
Eletronorte – Centrais Elétricas do Norte do Brasil / North Brazil power utility company
Emater – Empresa de Assistência Técnica e Extensão Rural / Technical Assistance and Rural Extension Company
Embrapa – Empresa Brasileira de Pesquisa Agropecuária / Brazilian Agricultural Research Corporation
Embrapii – Empresa Brasileira de Pesquisa e Inovação Industrial / Brazilian Industrial Research and Innovation Company
Epamig – Empresa de Pesquisa Agropecuária de Minas Gerais / Minas Gerais Agricultural Research Company
EPE – Empresa de Pesquisa Energética / Energy Research Company
Fapemig – Fundação de Amparo à Pesquisa do Estado de Minas Gerais / Minas Gerais State
FC – Brazilian Forest Code
Research Support Foundation
Fapesp – Fundação de Amparo à Pesquisa do Estado de São Paulo / São Paulo State Research Support Foundation
Fapeu – Fundação de Amparo à Pesquisa e Extensão Universitária / Foundation to Support University Research and Continuing Education
FBMC – Fórum Brasileiro de Mudança do Clima / Brazilian Climate Change Forum
Febraban – Federação Brasileira de Bancos / Brazilian Federation of Banks
FFEEAP – Fabricantes e fornecedores de equipamentos específicos em agricultura de precisão / Manufacturers and suppliers of specific equipment for precision agriculture
Finep – Financiadora de Estudos e Projetos / Financier of Studies and Projects
Fipe – Fundação Instituto de Pesquisas Econômicas / Economic Research Institute Foundation
FNDCT – Fundo Nacional de Desenvolvimento Científico e Tecnológico / National Scientific and Technological Development Fund
Firjan – Federação das Indústrias do Estado do Rio de Janeiro / Federation of Industries of the State of Rio de Janeiro
Funai – Fundação Nacional do Índio / National Indian Foundation
GCF – Green Climate Fund
Geneplus – Programa Embrapa de Melhoramento Genético de Bovinos de Corte / Embrapa Program for Genetic Improvement of Beef Cattle
GHG – Greenhouse gas
GI – Genetic improvement
GIS – Geographic Information System

HDI –	Human development index
HPP –	Hydroelectric power plant
IABr –	Instituto Aço Brasil / Brazil Steel Institute
Ibama –	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis / Brazilian Institute of Environment and Renewable Natural Resources
IBGE –	Instituto Brasileiro de Geografia e Estatística / Brazilian Institute of Geography and Statistics
ICLEI –	Local Governments for Sustainability
ICLFS –	Integrated crop-livestock-forestry system
ICMBio –	Instituto Chico Mendes / Chico Mendes Institute
ICS –	Instituto Clima e Sociedade / Institute for Climate and Society
Idesam –	Instituto de Conservação e Desenvolvimento Sustentável da Amazônia / Amazon Conservation and Sustainable Development Institute
Incra –	Instituto Nacional de Colonização e Reforma Agrária / National Institute for Colonization and Agrarian Reform
Inep –	Instituto de Pesquisas Educacionais / Educational Research Institute
Inma –	Instituto Nacional da Mata Atlântica / National Institute of the Atlantic Forest
Inmetro –	Instituto Nacional de Metrologia, Qualidade e Tecnologia / National Institute of Metrology, Standardization and Industrial Quality
Inpa –	Instituto Nacional de Pesquisas da Amazônia / National Amazon Research Institute
Inpe –	Instituto Nacional de Pesquisas Espaciais / National Institute for Space Research
Inpi –	Instituto Nacional de Propriedade Intelectual / National Institute of Intellectual Property
INT –	Instituto Nacional de Tecnologia / National Institute of Technology
IPAM –	Instituto de Pesquisa Ambiental da Amazônia / Amazon Environmental Research Institute
IPM –	Integrated pest management
IoT –	Internet of Things
ISO –	International Organization for Standardization
ITS -	Integrated Technology System
MAPA –	Ministério da Agricultura, Pecuária e Abastecimento / Ministry of Agriculture, Livestock and Supply
MapBiomas –	Projeto de Mapeamento Anual da Cobertura e Uso do Solo no Brasil / Brazilian Annual Land Use and Land Cover Mapping Project
MCom –	Ministério das Comunicações / Ministry of Communications
MCTI –	Ministério da Ciência, Tecnologia e Inovações / Ministry of Science, Technology and Innovations
MDR –	Ministério do Desenvolvimento Regional / Ministry of Regional Development
ME –	Ministério da Economia / Ministry of Economy
Minfra –	Ministério da Infraestrutura / Ministry of Infrastructure
MMA –	Ministério do Meio Ambiente / Ministry of Environment
MME –	Ministério de Minas e Energia / Ministry of Mines and Energy
MPEG –	Museu Paraense Emílio Goeldi / Emílio Goeldi Museum (State of Pará)

NDC –	Nationally Determined Contribution
NGO –	Non-governmental organization
NTU –	Associação Nacional das Empresas de Transportes Urbanos / National Association of Urban Transport Companies
Oemas –	Órgãos Estaduais de Meio Ambiente / State Environmental Agencies
ONS –	Operador Nacional do Sistema Elétrico / National Electric System Operator
Opex –	Operating expense
PA –	Precision agriculture
POF –	Pesquisa de Orçamento Familiar / IBGE Family Budget Survey
PPA –	Permanent Preservation Area
PRA –	Plano de Regularização Ambiental / Environmental Regularization Program
Prad –	Plano de Recuperação de Áreas Degradadas / Degraded Areas Recovery Plan
PTI –	Parque Tecnológico Itaipu / Itaipu Technological Park
RD&I –	Research, development and innovation
Rede Clima –	Rede Brasileira de Pesquisas sobre Mudanças Climáticas Globais / Brazilian Research Network on Global Climate Change
RenovaBio –	Política Nacional de Biocombustíveis / National Biofuels Policy
RL –	Reserva legal / legal reserve (preservation area)
SC –	TNA_BRAZIL Project Sectoral Chambers of Experts
Sebrae –	Serviço Brasileiro de Apoio às Micro e Pequenas Empresas / Brazilian Micro and Small Business Support Service
Seconci –	Serviço Social da Construção Civil / Construction industry social services
Senai –	Serviço Nacional de Aprendizagem Industrial / National Industrial Training Service
Senar –	Serviço Nacional de Aprendizagem Rural / National Rural Training Service
SFB –	Serviço Florestal Brasileiro / Brazilian Forest Service
Sicar –	Sistema Nacional de Cadastro Ambiental Rural / National Rural Environmental Registry System
Sigel –	Sistema de Informações Geográficas do Setor Elétrico / Geographic Information System for the Electricity Sector
SIN –	Sistema Interligado Nacional / National Interconnected System
Sinduscon –	Sindicatos da Indústria de Construção / Construction Industry Unions
SNIC –	Sindicato Nacional da Indústria do Cimento / National Cement Industry Union
SOFC –	Solid oxide fuel cell
SPE –	Secretaria de Planejamento e Desenvolvimento Energético (MME) / Energy Planning and Development Secretariat (Ministry of Environment)
TAC –	TNA_BRAZIL Project Technical Advisory Committee
TAP –	Technology Action Plan
TCA –	Technical Cooperation Agreement
TNA –	Technology needs assessment
UAV –	Unmanned aerial vehicle
UFF –	Universidade Federal Fluminense / Fluminense Federal University
UFMG –	Universidade Federal de Minas Gerais / Federal University of Minas Gerais

UFRJ – Universidade Federal do Rio de Janeiro / Federal University of Rio de Janeiro
Unesp – Universidade Estadual Paulista / State University of São Paulo
UNFCCC – United Nations Framework Convention on Climate Change
USP – Universidade de São Paulo / University of São Paulo

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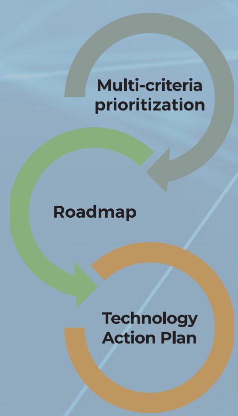
Introduction



Introduction

The "Technology Needs Assessment for the Implementation of Climate Action Plans in Brazil (TNA_BRAZIL)" project aims to strengthen the technical capacity of the Brazilian government through the development of a comprehensive assessment of technology needs for the implementation of climate action plans in Brazil, aimed at providing subsidies for decision making to support the GHG mitigation targets under Brazil's Nationally Determined Contribution (NDC) and the country's strategy for the Green Climate Fund (GCF).

The TNA_BRAZIL project, under the responsibility of the General Coordination for Climate Science and Sustainability (CGCL) of the Ministry of Science, Technology and Innovations (MCTI), with support from the United Nations Environment Programme (UNEP) and technical partners, is an ally of several initiatives to promote the economic, social and environmental sustainability of the country:

- The *Programa País do Brasil* [Brazil Country Program] for the Green Climate Fund (MF, 2018);
- Publication of the public notice and financing of BRL 50 million, based on the results of the project to support 4.0 Technologies in partnership with the Financier of Studies and Projects (Finep) (MCTI/FINEP, 2020);
- The 2020-2031 Federal Development Strategy for Brazil, which determines, as a guideline for Environmental efforts, the promotion of conservation and the sustainable use of natural resources to foster environmental quality as one of the fundamental elements of quality of human life, aligning environmental preservation with economic and social development (BRASIL, 2020);
- The National Strategy for Science, Technology and Innovation 2016-2022 (Encti) to promote sustainable development through the strengthening, expansion, consolidation and integration of the National Science, Technology and Innovation System (MCTIC, 2016);
- The *Regenera Brasil* Initiative, whose objective is to contribute to scientific research, technological development and innovation for the creation of guidelines to promote the recovery of native Brazilian ecosystems (MCTI, 2020);
- Brazilian Commission for Precision and Digital Agriculture (CBPAD), which aims to promote the development of precision and digital agriculture in the country (BRAZIL, 2019);
- Brazilian Chamber of Industry 4.0 (Câmara I4.0), whose objective is to incorporate the federal government public policies to promote industry 4.0, advanced manufacturing and Internet of Things (MCTIC/ME, 2019).

The TNA_BRAZIL project elaboration process has three phases: i) identification and prioritization of technologies for the selected sectors; ii) identification and analysis of value chains, co-benefits and the main barriers to the development and diffusion of the prioritized technologies; and iii) the proposition, based on the previous results, of Technology Action Plans (TAPs) to foster the development and diffusion of the prioritized technologies in each evaluated sector.

A TAP consists of an action plan that can address technological, training or diffusion matters, among others, and which translates into concrete actions to be implemented for the development and/or diffusion of technologies in the prioritized sectors. The actions, in turn, are divided into activities and should indicate the necessary resources for their implementation, including schedules, cost estimates and potential stakeholders to mobilize throughout the process. Furthermore, actions should be proposed to address implementation risks so that contingency measures can be adopted.

The first stage in preparing the Plans involved defining the technology packages, prioritizing the main critical links in the value chain and the barriers that, if not overcome, could prevent the development and/or diffusion of the technology. Once the priority barriers were identified, the scopes, goals and scales of the Plans were defined. In this regard, it is important to highlight the alignment of the time frame for the contribution of the project results (which is 2030) with Brazil's Nationally Determined Contribution (NDC) under the Paris Agreement. Subsequently, the actions and activities necessary for executing the Plan were defined. It is important to note that, although these are individual plans, the actions proposed in a plan can have synergy and benefit TAPs for other technologies. The next steps consisted of proposing an implementation schedule, as well as identifying potential stakeholders to mobilize and the estimated costs for carrying out the actions. Following this, the activity implementation risks were evaluated and contingency actions were proposed to mitigate these risks. Finally, project ideas were proposed based on Action Plan subsidies, with a view to fostering the development and diffusion of the prioritized technologies.

The project phases and plan preparation stages are summarized in the figure below.

MULTI-CRITERIA PRIORITIZATION OF TECHNOLOGIES

Phase 1

- Evaluation of 450 emission mitigation technologies
- Definition of 82 technology packages with development and/or dissemination gaps
- Definition of 4 macro-criteria and 15 indicators for multi-criteria assessment of the technologies
- Application of the multi-criteria methodology by the Sectoral Chambers, Technical Advisory Committee and the General Coordination for Climate Science and Sustainability team
- Scoring, ranking and prioritization of the technology packages

ANALYSIS OF VALUE CHAINS, BARRIERS AND CO-BENEFITS

Phase 2

- Evaluation of the technology package value chains and the prioritized sectors
- Mapping of barriers (Appendix I) and the development and diffusion co-benefits of the prioritized technologies
- Validation of results by the Sectoral Chambers and Technical Advisory Committee

ELABORATION OF THE TECHNOLOGY ACTION PLANS

Phase 3

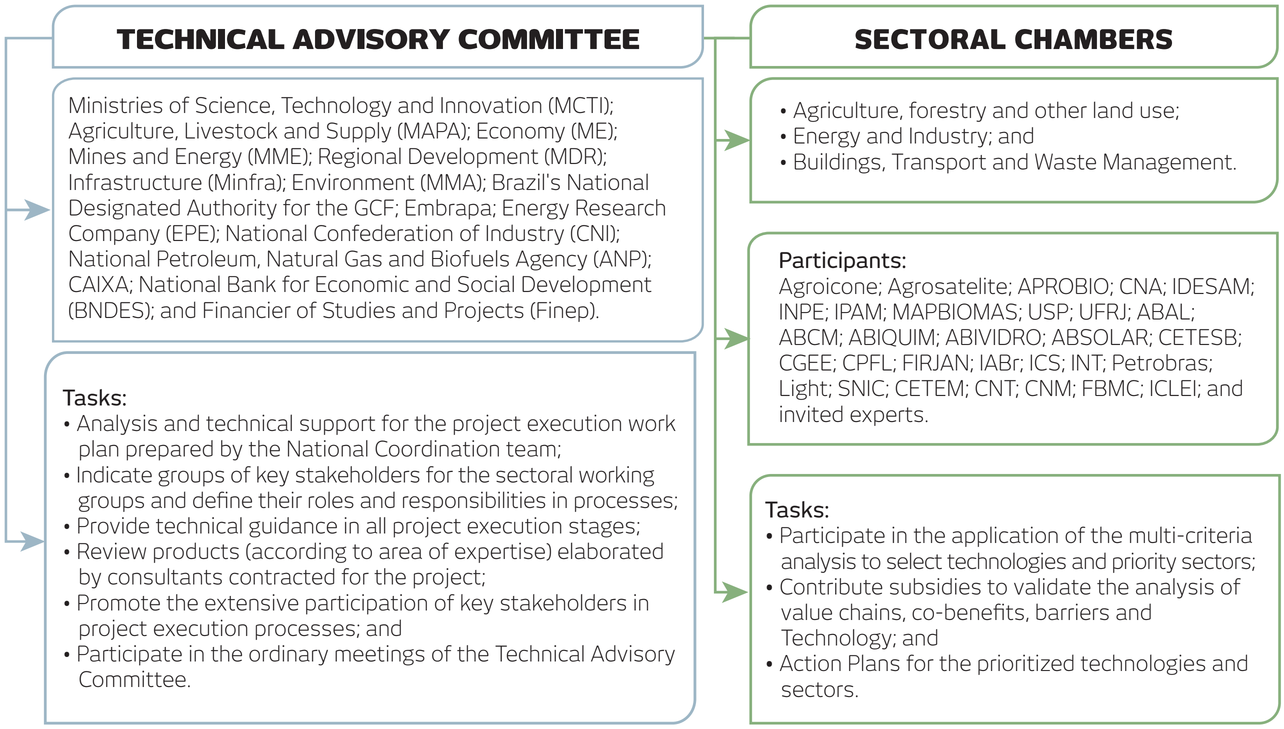
- Definition of critical technologies in technology packages
- Prioritization of critical gaps and barriers
- Definition of scope, goals and scale of the Plans
- Proposal of actions and activities
- Elaboration of schedules and implementation costs
- Identification of stakeholders to be mobilized
- Risk and contingency plans
- Project ideas
- Validation of results by the Sectoral Chambers and Technical Advisory Committee

Figure 1 – TNA_BRAZIL Project preparation phases
Source: the author.

It should be noted that there was a comprehensive discrimination of costs in the TAP actions and activities according to the following categories: human resources; permanent materials; consumables; third-party services, travel expenses; and other costs. All information was systematized in MS-Excel spreadsheets and the National Directorate of the TNA_BRAZIL project will make these available to stakeholders interested in submitting project proposals.[1] This procedure allows the National Directorate of the Project to monitor the evolution of the implementation of the Plans by interested stakeholders.

In the energy system, agriculture, forestry and other land use sectors, the following technology packages were prioritized (the action plans are presented below): floating solar power plants; flex hybrid vehicles; ethanol fuel cell electric vehicles; energy generation from agricultural and agro-industrial waste; photovoltaic solar induction stoves; innovative materials for cement; industry 4.0; precision agriculture (PA); genetic improvement (GI) of beef cattle; silviculture and genetic improvement of native species; silviculture with mixed planting systems for restoration; and satellite monitoring.

Meetings to validate the TAPs were conducted between March and November of 2020 with members of the Technical Advisory Committee (TAC) and Sectoral Chambers (SCs) of the project (Figure 2 and Appendix II). They were systematized using matrices, resulting in improvements in the plans (MCTI, 2020a; 2020b). The participation of key stakeholders was fundamental for the robustness of the Plans, which were widely disseminated on official MCTI channels (MCTI, 2020c) and in seven webinars held between October and December of 2020 (MCTI, 2020c-2020i). It should be noted that the Minister of Science, Technology and Innovations inaugurated the cycle of events (MCTI, 2020j; 2020k).



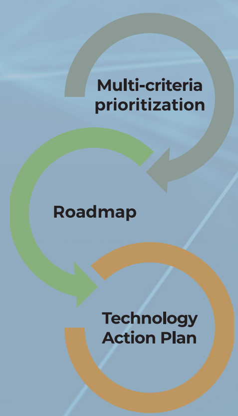
Source: the author.

Next, we present the TAPs, by technology, and project ideas that share a synergy in scope and goals. The conclusions are presented at the end of this document.

[1] Send requests for access to the spreadsheets, specifying the Action Plan, to tna@mctic.gov.br.

1.

Technology Action Plan **for Floating Solar Power Plants**



1. TECHNOLOGY ACTION PLAN FOR FLOATING SOLAR POWER PLANTS

1.1. Definition of technology

Different from conventional photovoltaic systems, floating solar systems employ a panel support structure with floats and an anchoring system. It must ensure the photovoltaic panels can resist the forces of winds, waves and currents. Floating solar power plants can be installed in lakes, ponds, reservoirs, channels or dams, among other bodies of water.

In addition to being a safe and renewable energy source that contributes to GHG emission reductions in the electricity sector, floating solar energy can generate other benefits, especially when associated with hydroelectric power plant (HPP) reservoirs.

Importantly, compared to land-based solar power plants, with floating solar there is a potential gain in energy production due to the cooling effect of water in contact with the panels and the low probability of shading from structures, both of which improve the efficiency of the system. In addition, there are fewer chances of conflict with other priority land uses, such as agriculture. Another benefit is that floating solar power plants are modular and can be installed in remote areas where it is not possible to install solar panels on land, either due topography (such as mountains) or the high price or scarcity of available land, contributing to the use of renewable energy in these areas.

When installed in HPP reservoirs, floating solar plants offer a number of synergistic benefits with hydroelectric generation. From an economic point of view, there is the benefit of low capital costs for infrastructure to connect to the power grid, since it is possible to take advantage of the HPP transmission lines and substations. Floating solar can also help to compensate seasonal variability in hydroelectric power generation, with the reservoir serving as a storage system for the photovoltaic system, improving the energy security of the system as a whole. Furthermore, covering the water surface with floating solar can increase the availability of water in the reservoirs for other uses, such as water supply and navigation, due to the decrease in the proliferation of algae and evaporation in reservoirs.

From an environmental perspective, covering the reservoir surface with solar panels may have adverse effects, which are still poorly understood. However, by reducing abnormal algae proliferation, it also reduces the eutrophication of the aquatic environment that leads to poor water quality for aquatic species. The panel structures can also serve as a shelter for some aquatic species due to the shading and temperature reduction in the water column below the floating panels. Finally, the installation of floating solar plants in HPP reservoirs avoids new areas being impacted, and reduces the magnitude of the potential impacts that a solar project and its supporting infrastructure would cause.

Thus, the installation of floating solar systems in HPP reservoirs is particularly interesting in Brazil, given that the country has a well-developed hydroelectric generation system. Although there are pilot projects for floating solar plants in HPP reservoirs in operation in the country, this type of hybrid generation plant is still developing around the world and some challenges need to be overcome to achieve greater development of the energy source.

1.2. Scope and goals

The goal of the TAP is to develop an inventory of the floating solar energy potential in Brazil and identify the barriers to its development, such as the lack of understanding of its sustainable potential in Brazil, lack of knowledge of the technology and its benefits, and the legal and regulatory uncertainties concerning management obligations for HPP reservoirs where future projects may be installed. Given this scenario, the inventory goes beyond simply mapping solar resources and reservoirs, and includes environmental, social and economic data considered important for decision making for the installation of floating solar plants in HPP reservoirs.

To this end, the scope of the TAP is to identify the viable and sustainable potential for installing floating solar power projects in reservoirs in Brazil to support auctions for the technology. The goal is to develop a national inventory of floating solar energy potential, taking into account restrictions, in order to anticipate impacts and identify critical aspects of the technology for the different types and conditions of reservoirs across Brazil.

Table 1 – TAP scope and goals

SCOPE	GOALS
Identify the viable and sustainable potential for the installation of floating solar energy projects in reservoirs in Brazil to support auctions for the technology.	Develop a national inventory of floating solar energy potential, taking into account restrictions, in order to anticipate impacts and identify critical aspects of the technology for the different types and conditions of reservoirs across Brazil.

Source: the author.

1.3. Actions and activities

Critical gaps and barriers and means to overcome them

Initially, we identified critical gaps in the floating solar energy value chain in Brazil and the main barriers to the development of technology on a national scale. Among the critical gaps we identified, the lack of solar potential mapping was considered a priority challenge, as it delays the development of projects and the diffusion of the technology in the country.

Some issues have to be addressed for the mapping of the energy source potential to contribute effectively to its development. In the electricity sector (and in terms of comparison to other sources), the potential of a renewable energy source depends not only on its technical and economic characteristics, but also the guarantee of sustainability, co-benefits, and the possibility of implementing projects in the current regulatory and institutional context.

Thus, the first barrier to mapping floating solar potential is technical and related to the current lack of mapping. In other words, there is a need to collect specific data to map the areas available for the installation of projects, taking into account sustainability as well as environmental and social restrictions that may conflict with their implementation, especially in view of the multiple uses of HPP reservoirs in Brazil.

In addition, as it is an emerging energy source in the country, little is known about the technology and its benefits. Due to this cultural barrier, it is often not considered as a power generation option to be disseminated, especially given the other renewable energy sources currently developed in the country, leading to a lack of interest in understanding its potential.

We identified a lack of clarity with respect to reservoir use rights and management obligations, given that reservoirs generally have multiple uses that must be protected and guaranteed, such as navigation, water supply, tourism, leisure, fishing and environmental preservation areas. Regarding the specific regulatory and administrative regulations on the use and concession of reservoir waters, these are still being defined by the competent institutions. Thus, this institutional barrier undermines business interest in the technology, and there is a need to clarify these issues at the reservoir and institutional level when considering the potential of the energy source.

In order to address these barriers, we propose compiling an inventory of floating solar energy potential in Brazil that aggregates data necessary for decision making. Thus, this data is related not only to the specifics of the technology itself, but also to environmental, social and regulatory aspects of its implementation in HPP reservoirs in Brazil. The proposal of actions and activities to remove these barriers, as well as dialogue with the institutions and stakeholders involved in the different spheres to be analyzed, can support the dissemination of the energy source in the country.

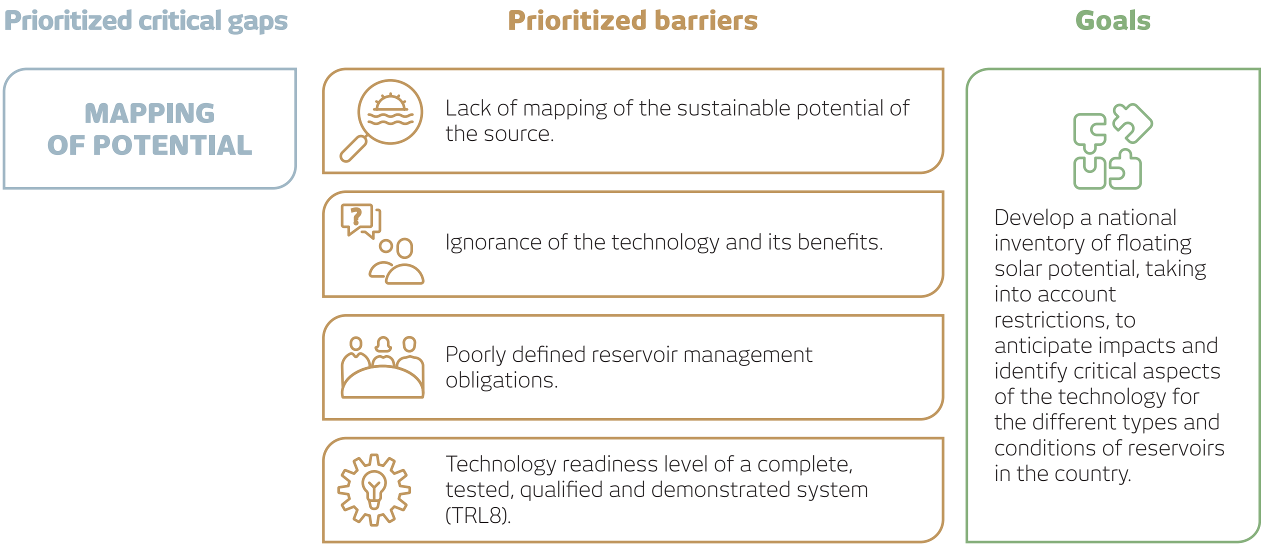


Figure 3 – Critical gaps and barriers and priority goals

Source: the author.

Actions and activities

In this section, we present the steps, divided into actions and their respective activities, for the execution of the TAP for floating solar power plants. They are related to the collection of data on HPP reservoirs in Brazil, the quantification of the solar resource on water surfaces and spatial analysis (aggregating the data and generating mapping results), aimed at the elaboration and dissemination of a national inventory of floating solar potential in Brazil.

With the goal of covering the vast national territory and, at the same time, ensuring the accuracy of the data, the Plan has two stages. The first, which encompasses the first two actions, consists of a broader analysis, in which existing data is collected on HPP reservoirs across the country. This data refers to the solar resource and climatic conditions that can affect solar photovoltaic power generation and includes basic reservoir data, such as location and size. Following this, a preliminary mapping of floating solar technology potential on a national scale can be carried out.

From the national mapping, the analysis can be improved. To this end, we propose selecting five promising reservoirs in Brazil, preferably in different bio-climatic zones, to serve as standard projects that can be replicated in other areas. With the selected reservoirs, the second phase involves estimating the solar resource on the water surface with greater precision and collecting high-resolution spatial data and specific data for the precise mapping of the available areas to install solar plants. Thus, it is possible to assess the national potential of the energy source, in terms of power generation and costs for future projects, based on these standard reservoirs. The results of this detailed analysis can help to anticipate impacts and challenges and to identify the critical technological specifications for the different reservoir types and conditions in Brazil, according to the TAP goals.

In addition to the preliminary mapping of floating solar potential on a national scale and detailed case studies of the five most promising reservoirs, the Plan will indirectly provide a methodology for identifying locations for installing floating solar energy projects in HPP reservoirs in Brazil. Moreover, it will include a high resolution spatial database for the analyzed reservoirs, and an analysis that can support discussions on the feasibility of developing floating solar on a national or regional scale.

Action 1 and related activities

The first action aims to collect and analyze the available data for Brazil. To achieve this objective, the first activity involves gathering the available estimated solar resource data on Brazil in order to identify the areas with the greatest potential for solar energy generation.

Following this, other climate data should also be collected, such as average monthly variations in temperature, precipitation, wind speed and direction and humidity, which may affect solar electricity generation and indicate a preference for certain locations, when analyzed in conjunction with the solar resource data.

In addition to climate data, other data on Brazilian HPP reservoirs should be gathered, including mapping the location, area and outline of the reservoir (preferably georeferenced) to provide its exact location and total area. Other important data include reservoir management rights, whether public or private, and priority uses (which can go beyond electricity generation), such as navigation, water supply, tourism, leisure, fishing and aquaculture, among others.

Finally, in sub-activity 1.4, the collected data should be subjected to statistical and econometric analysis, with possible corrections of gaps in the measured historical data series.

Table 2 – Action 1 and related activities

ACTION 1 – DATA COLLECTION AND ANALYSIS	
Sub-activity 1.1	Preliminary solar resource data collection
Sub-activity 1.2	Local climate data collection
Sub-activity 1.3	Collection of data on HPP reservoirs
Sub-activity 1.4	Statistical and econometric analysis of data, with possible corrections of gaps in the data series

Source: the author.

Action 2 and related activities

Action 2 consists of the elaboration of the preliminary mapping of the potential for installing floating solar power plants in HPP reservoirs in Brazil and identifying promising reservoirs to improve the analysis.

To achieve this, sub-activity 2.1 involves defining the spatial restrictions for the installation of floating solar plants using bibliographic research and analysis of international best practices in the sector. In addition to technical feasibility, this ensures continuestion of the shared and sustainable use of reservoirs, minimizing potential conflicts with other activities.

Based on this, sub-activity 2.2 seeks to develop a methodology for assessing areas suitable for the installation of floating solar plants in HPP reservoirs in Brazil, with the definition of their respective criteria and limits. This activity also includes the subsequent validation of the methodology by competent national agencies and institutions.

The mapping itself is performed in sub-activity 2.3, which consists of a spatial analysis in a Geographic Information System (GIS), using all the data collected. The processing should include the cross referencing of data and the application of the defined restrictions to map the available reservoirs for installing floating solar plants.

Finally, after the preliminary mapping, sub-activity 2.4 involves the selection of five promising reservoirs, so that the analysis can be improved with the acquisition of specific data with higher spatial resolution, since it is not feasible to do so for all reservoirs in the country.

The selection of promising reservoirs should prioritize reservoirs that have different bioclimatic conditions, aimed at assessing the potential by region or biome. However, the criteria used in the selection should not be expressly defined, given the assumption that the most promising reservoir in one bioclimatic zone may not very promising in relation to other reservoirs in Brazil (thus a deeper analysis at this stage is not required).

Table 3 – Action 2 and related activities

ACTION 2 – PRELIMINARY MAPPING AND IDENTIFICATION OF PROMISING RESERVOIRS	
Sub-activity 2.1	Definition of spatial restrictions on the installation of floating solar plants in HPP reservoirs
Sub-activity 2.2	Definition and validation of methodology, criteria and limits
Sub-activity 2.3	Inclusion of collected data in geographic information system for preliminary mapping of reservoirs
Sub-activity 2.4	Selection of five promising reservoirs to specify the solar resource

Source: the author.

Action 3 and related activities

Once the five promising reservoirs have been selected, the analysis can be further developed. An important requirement for improving the data is the specification of the solar resource on the water surfaces of reservoirs, given that, due to uneven cloud cover, for example, there may be differences between the estimated resource on land and water surfaces. Thus, Action 3 addresses this particular requirement.

In Brazil, Inpe has been leading the effort to estimate the solar resource on water surfaces using a satellite radiative transfer model. To achieve this, the model should be calibrated by comparing the modeled resource with actual conditions. Thus, the first activity of this action involves the installation of solarimeter buoys to measure the solar resource in the selected reservoirs. Measurements should be carried out over a full year to include seasonal variability and climatic factors.

Sub-activity 3.2 includes simulations with a satellite radiative transfer model for water surfaces. Finally, following the measurement period and modeling, the solar potential on the surfaces of the five selected reservoirs can finally be estimated with great precision, which occurs in sub-activity 3.3.

Table 4 – Action 3 and related activities

ACTION 3 – SPECIFICATION OF THE SOLAR RESOURCE IN THE SELECTED RESERVOIRS	
Sub-activity 3.1	Installation of solarimeter buoys to measure the solar resource in selected reservoirs
Sub-activity 3.2	Simulations with satellite radiative transfer model for water surfaces
Sub-activity 3.3	Generation of data on the solarimetric potential of reservoirs, calibrated from observations taken from the buoys

Source: the author.

Action 4 and related activities

Detailed analysis of the five selected reservoirs goes beyond the estimation of the solar resource on the water surface, and includes, in Action 4, the collection of primary high-resolution spatial data to determine the technical specificities of projects. It is important to note that Actions 3 and 4, as well as the following activities, are independent and can be carried out in parallel.

The first activity involves carrying out detailed mapping of the reservoir perimeter and area, and an analysis of the surrounding topography to determine shading on the water surface, which can compromise solar power generation on certain areas of the reservoir surface.

Following this, sub-activity 4.2 involves the elaboration of the bathymetric profile of the reservoirs (the bottom relief and depth ranges, including the water level variations resulting from the operation of HPP reservoirs). The bathymetric report data informs the choice of location for the solar plant and the anchoring system.

The next activity involves the analysis of the soil type, composition and properties of the bottom and banks of the selected reservoirs to estimate the technical requirements of the anchoring and supporting infrastructure of the floating solar projects.

Another important analysis, which is part of sub-activity 4.4, concerns access to the grid and substation capacity. As the use of HPP electrical infrastructure is one of the main advantages of installing floating solar energy projects in reservoirs, it is necessary to assess whether the power of the substations and grid is compatible with the addition of solar generation.

Another advantage of installing floating solar plants in HPP reservoirs is that they are implemented in areas that have already been impacted and, therefore, already assessed. Thus, sub-activity 4.5 consists of the elaboration of a preliminary socio-environmental analysis to describe the main environmental and social characteristics of the project area. It is a preliminary analysis that is simplified by using the Environmental Impact Assessment (EIA) of the HPPs and the collection of specific additional data on site. The idea is to identify the main environmental relationships at the site to estimate possible project impacts on fauna and flora and on human activities, and vice versa. This step is not a substitute for the environmental studies required to obtain licenses for projects, as stipulated by governing environmental agencies.

Table 5 – Action 4 and related activities

ACTION 4 – PRIMARY DATA COLLECTION ON SELECTED RESERVOIRS	
Sub-activity 4.1	Reservoir mapping and topographic study of the surroundings
Sub-activity 4.2	Elaboration of the bathymetric profile, including reservoir water level variations
Sub-activity 4.3	Analysis of the soil profile of reservoir bottoms and banks
Sub-activity 4.4	Analysis of grid access and substation capacity
Sub-activity 4.5	Preliminary socio-environmental analysis of the reservoirs

Source: the author.

Action 5 and related activities

Following the collection of specific and high-resolution spatial data on the five reservoirs selected in Actions 3 and 4, the mapping and calculation of the potential can be accurately performed in Action 5.

In sub-activity 5.1, similar to sub-activity 2.3, the specific and high-resolution spatial data on the selected reservoirs should be included and processed in the GIS. Spatial data should be cross-referenced for each reservoir, using the criteria and limits previously established in Action 2.

Then, in sub-activity 5.2, it is possible to define and calculate the area available for the installation of floating solar plants in the five selected reservoirs. This zoning process can guide the selection of the best areas for the installation of future projects, reducing potential risks and conflicts.

Based on the mapping, sub-activity 5.3 involves the development of pre-projects, defining solar panel placement according to the specifications of the selected reservoirs.Total costs should be estimated to produce a preliminary feasibility analysis of projects per reservoir.

Finally, sub-activity 5.4 involves the calculation of the potential for solar generation in the selected reservoirs. From the pre-projects, it is possible to estimate power generation in each of the five reservoirs. This allows for the evaluation of the potential of floating solar energy in terms of technical, environmental, social and economic viability in the most promising reservoirs in the country.

Table 6 – Action 5 and related activities

ACTION 5 – MAPPING AND CALCULATION OF THE POTENTIAL IN THE SELECTED RESERVOIRS	
Sub-activity 5.1	Cross referencing and geoprocessing of the data collected for the selected reservoirs with the spatial restrictions defined in the methodology
Sub-activity 5.2	Definition of the areas available for the installation of floating solar plants in each selected reservoir
Sub-activity 5.3	Development of pre-projects according to the specifications of the selected reservoirs and estimation of project costs
Sub-activity 5.4	Calculation of solar generation potential in selected reservoirs

Source: the author.

Action 6 and related activities

The last TAP action concerns the preparation and digital sharing of the inventory. Thus, the first activity is the preparation of the final consolidated inventory, which consists of a text document detailing the steps taken and the results, including the reports and mapping.

Subsequently, sub-activity 6.2 involves the creation of an on-line digital platform to disseminate the inventory, in both its text format and as an interactive map, for viewing and downloading, aggregating all the georeferenced data collected and produced during the course of preparing the inventory. It should be emphasized that the strategy for developing and disseminating the platform, and defining the target user, will be based on a communication plan prepared at the beginning of this activity.

Finally, it is important to ensure that the inventory and data produced are permanently maintained. However, maintaining a digital platform can be a challenge for any institution, and a solution could be hosting it, preferably, on existing public platforms, such as the Geographic Information System of the Electric Sector (Sigel), the National Electric Energy Agency (Aneel), and EPE's WebMap. Thus, sub-activity 6.3 consists of the transfer of the digital platform to a partner institution, such as the Federal Research Institute, the EPE or Aneel, to disseminate the inventory to the Plan's stakeholders.

Table 7 – Action 6 and related activities

ACTION 6 – ELABORATION OF INVENTORY AND ONLINE DISSEMINATION	
Sub-activity 6.1	Elaboration of texts, layout and translation of the inventory
Sub-activity 6.2	Creation of a digital platform for interactive on-line use of the database with final inventory results
Sub-activity 6.3	Transfer of the platform to a Federal research institute, EPE or Aneel

Source: the author.

1.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

The TAP for floating solar in HPP reservoirs involves an emerging technology with no regulatory framework for it in the country. Implementation depends on a national planning strategy. Thus, the success of the project requires the participation and contribution of multiple stakeholders. Furthermore, as several actions involve data collection, the engagement of different stakeholders is essential for their execution, and to ensure access to the data. For this reason, the stakeholders to mobilize include public sector authorities, regulatory and inspection agencies, technical and scientific support institutions (including universities and research centers), the private sector and institutions that support and promote science and technology.

It is a highly technical and multidisciplinary project to execute, involving data collection and production and spatial and energy analysis. Ideally, the coordination and/or Results Validation Committee should be a partnership between a public institution in the energy sector, such as the MME and/or EPE, and an institute or research group with expertise in climate and energy studies that has the expertise to carry out the actions (such as Inpe). Alternatively, TAP Actions 4 and 5 could be carried out by HPP concessionaires interested in expanding their power generation capacity.

Especially for Action 3, which is the most specific, costly and long-term TAP action, it is essential that Inpe be responsible for technical coordination, given that it is the research center with the greatest expertise and the best computational infrastructure to carry it out. Furthermore, Inpe has been leading the effort to map the solar resource on water surfaces in Brazil. Contracted specialized companies, under the coordination and supervision of the TAP coordinating institution, should carry out some activities, such as those in Action 4, which involve specific technical studies.

Table 8 – Main stakeholders to involve in implementing the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
MME	The Ministry of Mines and Energy (MME) establishes guidelines for the elaboration of public policies for the energy sector and coordinates the elaboration and implementation of Brazilian energy planning instruments, such as the Ten-Year Energy Expansion Plan, the National Energy Plan and the National Energy Balance, in addition to coordinating energy data systems. It also evaluates the analysis for granting concessions, authorizations and licenses to use public assets for electricity services, as well as coordinating strategic actions and plans to implement national policies aimed at the development of alternative energies, energy efficiency and environmental sustainability. The MME could play a role in the coordination and/or governance for the validation of TAP results.
EPE	In 2020, the Energy Research Company (EPE) launched the "Technical Note for Expansion of Floating Photovoltaic Solar Generation: technological and environmental aspects relevant to planning" (EPE, 2020). It could assist in all TAP actions with technical data, methodological processes and validation. The EPE could be part of the coordination and/or governance structure for the validation of TAP results. Moreover, with respect to sub-activity 6.3, it could host and disseminate the contents of the digital platform.
Inpe	The National Institute for Space Research (Inpe) is a Federal institute that seeks to promote space and earth sciences and technology and offers specialized products and services that benefit the country. The research institution is responsible for the elaboration of the Brazilian Solar Atlas and for mapping the solar resource on water surfaces in Brazil. It could participate in the execution and/or technical coordination of TAP Actions 1, 2, 3 and 5, as it is the research center with the greatest expertise and computational infrastructure in Brazil to carry out Action 3.

continues

continuation

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
ONS	The National Electric System Operator (ONS) is the body responsible for coordinating and controlling the operation of electricity generation and transmission facilities in the National Interconnected System (SIN) and for planning the operation of the country's isolated systems, under the supervision and regulation of Aneel. The ONS could assist with the data collection in Action 4 of the TAP.
ANA	The National Water Agency (ANA) regulates access and use of Federal water resources and public irrigation services (if under concession) and the raw water supply. In addition, it issues and enforces compliance with standards, especially concessions, and is responsible for overseeing the safety of the dams granted by the agency. It is responsible for monitoring Brazil's water resources, in addition to (in collaboration with the ONS) defining the operating rules for HPP reservoirs to ensure that all sectors that share the reservoir have access to the water. ANA could assist with the collection of climate data and information on HPP reservoirs in TAP Actions 1, 2 and 4, in addition to methodological and validation contributions related to the regulatory and institutional scope.
Aneel	The National Electric Energy Agency (Aneel) regulates the generation, transmission, distribution and commercialization of electricity; oversees electric energy concessions, authorizations and services; implements the Federal government policies and guidelines for the exploitation of electric energy and use of hydraulic potentials; establishes tariffs; resolves differences, at the administrative level, between agents and between agents and consumers; promotes the activities for granting concessions, licenses and authorizations for electric energy projects and services under Federal government delegation. It can assist with data collection in TAP Actions 1 and 4, in addition to methodological and validation contributions in Actions 3 and 5. It could also host the digital platform (sub-activity 6.3).
Port and river authorities	The Port and River Authorities, Police and Agencies oversee, coordinate and control the activities of the Merchant Navy and related organizations to ensure and enforce navigation safety, national defense, the safeguarding of human life and the prevention of water pollution. They could provide information on other uses of HPP reservoir waters in Action 4.
Ibama	The mission of the Brazilian Institute of Environment and Renewable Natural Resources (Ibama) is to protect the environment, ensuring environmental quality and the sustainable use of natural resources. It is a federal authority. It could assist with information and/or the validation of socio-environmental analyses of the projects in Action 4, as well as aspects of the methodology related to project licensing.
State environmental agencies	The state environmental agencies execute state environmental policies. They could assist with information for the socio-environmental analyses of projects in Action 4 and with aspects of the methodology related to project licensing.
Cepel	The Electric Energy Research Center (Cepel) has an advanced infrastructure for applied research in electrical systems and equipment, and develops and provides technological solutions for the generation, transmission, distribution and commercialization of electric energy in Brazil. It is a reference in Brazil and abroad. It is the central executor of its research, programs and projects, and provides consulting services for the evaluation of results and the management of technological knowledge and its application. It could offer institutional support and/or assist in the validation of the results of Actions 1, 3 and 5.
CPRM	The Geological Survey of Brazil (CPRM) is a public company, linked to the MME, assigned with the task of conducting the country's geological survey. Its mission is to generate and disseminate geoscientific knowledge with excellence, contributing to the improvement of quality of life and the sustainable development of Brazil. It could assist by providing technical data on soils and bathymetry in TAP Actions 1 and 4.
Federal research institutes	Federal research institutes are responsible for producing technical and scientific knowledge of excellence to benefit the country. They could assist in this TAP by providing technical data, methodological processes and validation throughout the project. In addition, one of these institutes could host the digital platform (sub-activity 6.3).

continues

continuation

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Universities and research centers	These institutions produce excellent technical and scientific knowledge in Brazil and could contribute to the TAP with technical data, methodological processes and validation throughout the project. Furthermore, depending on their areas of expertise, they could assist in the execution of TAP activities.
HPP Concessionaires	HPP Concessionaires are responsible for the management of hydroelectric reservoirs and have knowledge of their characteristics and ongoing activities. They could be responsible for environmental monitoring programs, social actions and tourism activities in the reservoirs and hydroelectric plants. They could contribute information on HPP reservoirs in TAP Actions 1, 4 and 5, as well as benefiting as users of the inventory (Action 6).
Chesf	The São Francisco Hydroelectric Company (Chesf) is an electricity sector company and subsidiary of Eletrobras whose main activity is the generation, transmission and commercialization of electricity. It is the concessionaire of the Sobradinho HPP reservoir in Bahia, where a research and development project for a 1 MWp floating solar power plant is installed. It could contribute, especially, with information on the research and development project at the Sobradinho HPP.
Eletronorte	The North Brazil Power Utility Company (Eletronorte) is an electricity sector company and subsidiary of Eletrobras whose main activity is the generation, transmission and commercialization of electricity. It is the concessionaire of the Balbina HPP reservoir in Amazonas, where a research and development project for a 1 MWp floating solar power plant is installed. It could contribute, especially, with information on the research and development project at the Balbina HPP.
Companies in the floating solar supply chain	Companies like F2B and Sunlution, among others, could provide data on floating solar energy technology for developing sub-activities 5.3 and 5.4.
BNDES	The National Bank for Economic and Social Development (BNDES) is the main instrument of the Federal Government for long-term financing and investment in all segments of the Brazilian economy. It could act as a financing agency for TAP activities
CNPq	The National Council for Scientific and Technological Development (CNPq) promotes and fosters scientific and technological development in Brazil and contributes to the formulation of national science and technology policies. It could act as a TAP financing agency.
Embrapii	The Brazilian Industrial Research and Innovation Company (Embrapii) supports technological research institutions, in selected areas of competence, to carry out technological research development projects for innovation in cooperation with companies in the industrial sector. It could play a role in developing and promoting the technology.
Finep	The Financier of Studies and Projects (Finep) promotes the economic and social development of Brazil through the public promotion of science, technology and innovation in companies, universities, technological institutes and other public and private institutions. It could act as an agent to promote TAP activities.

Source: the author.

Schedule of actions and activities

The time frame for implementing the action plan is five years, a time that is believed adequate and sufficient for the technical and financial preparation and implementation of activities for developing the floating solar TAP.

Most actions and activities are interdependent and should follow the proposed order of execution. There are exceptions, such as activities that involve the collection of different kinds of data, which can be carried out independently. It is important to note that some activities within the same action have a short duration (less than 6 months) and, even though they are sequential, they are presented in the same execution semester in the schedule.

Actions 3 and 4, in particular, can be carried out in parallel once the five most promising reservoirs have been selected. In addition, Action 4 involves five independent activities to collect different types of data on the selected reservoirs. In contrast, in Action 3, sub-activity 3.3 depends on the completion of the previous activities. This is the longest scheduled activity, given that a minimum of one year of measurement data is required in sub-activity 3.1. Thus, Action 5 can only commence after Action 3 is completed.

Another aspect of Action 3 is that it starts in the same semester as Action 2, even though they are sequential actions. This is because, prior to the installation of buoys in sub-activity 3.1, a period was suggested for preparing and signing TCAs for monitoring and maintaining the instruments. Once Action 2 is concluded, and the reservoirs are selected, technical cooperation agreements can be signed so that the installation of the buoys can begin in the third semester of the schedule.

Table 9 – TAP implementation schedule

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
1.1	■																	
1.2	■																	
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2.1		■																
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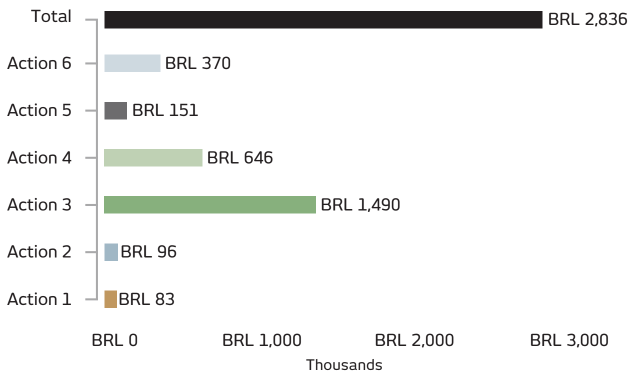
5.1							■											
5.2							■											
5.3							■	■										
5.4							■	■										
6.1									■									
6.2									■	■								
6.3										■								

Source: the author.

1.5. TAP implementation costs and financing options

The following are the cost estimates per action. The total cost of the TAP was estimated at approximately BRL 2.8 million. Actions 3 and 4 are the most significant in terms of costs, which involve, respectively, the production of data on the solar resource on water surfaces and specific high-resolution data for reservoirs.

The cost estimates for all actions include the contracting of staff, materials, possible third-party services and travel and accommodation costs. In Action 3, for example, the costs for installing and maintaining the solarimeter buoys in sub-activity 3.1 are already included, as well as the costs for data storage and processing on-site and in the cloud in sub-activity 3.2.



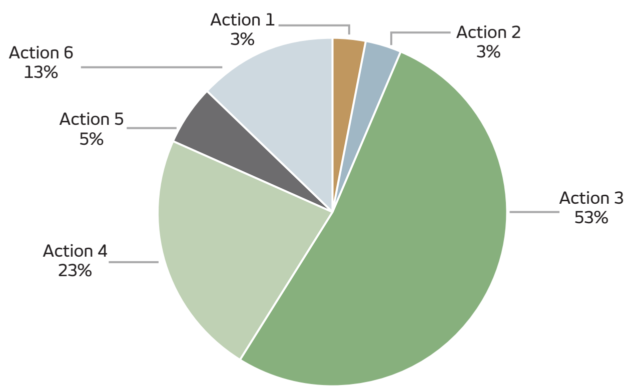


Figure 4 – Total costs, per action, in thousands of BRL and as a percentage, for the floating solar TAP

Source: the author.

With respect to potential sources of financing for the activities, and with a view to financial results and a focus on research and development aimed at the subsequent diffusion of the technology in relation to Actions 1, 2 and 3, we determined the typical means of financing would be non-repayable loans and technical assistance. Financing is accessible for state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives. Actions 4 and 5 may also obtain financing from repayable loans, as these actions may provide additional revenues for HPP concessionaires from the generation of energy from floating solar.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and in the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b).

1.6. Risk and contingency plan

We analyzed the potential risks involved to implement the TAP activities. The following risk categories were considered: political, institutional, organizational, technical and cost risks. They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs). Finally, contingency actions were proposed to mitigate these risks.

The high risks are associated with Action 3, which is the longest in duration and the most expensive in the TAP, and with sub-activity 5.2. Sub-activity 3.1 could be hindered by technical problems or failures of the measuring instruments, which represent a high risk with serious consequences for the progress of the rest of the project. The first measure to deal with these risks is to install redundant sensors on the solarimeter buoys. Furthermore, prior to the installation of the instruments, we propose a period of six months to establish TCAs with the HPP reservoir concessionaires and local science and technology institutes for monitoring and maintenance of the instruments during the measurement period.

Sub-activity 3.2 could be undermined by the contracted party's computational limitations, which represents a high risk with serious consequences for the progress of the rest of the project. To mitigate this risk, the technical capacity and computational infrastructure to support the modeling should be ensured in a clause in the modeling consulting contract. Moreover, a budget was foreseen to contract computational resources for on-site and remote cloud modeling.

Sub-activity 5.2 involves applying the previously defined methodology to determine available areas for installing floating solar plants in HPP reservoirs, taking into account technical, environmental and social restrictions. However, given the lack of an environmental regulatory framework and clear use rights, it is possible that the methodology applied in sub-activity 5.2 will not be applicable in future projects, as restrictions and criteria for granting licenses and concessions may change. Thus, it is essential that regulatory and environmental agencies participate in the validation of the methodology for defining areas.

Table 10 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1 Preliminary data collection on the solar resource 1.2 Local climate data collection 1.3 Data collection on HPP reservoirs	Technical risk and organizational risk	Difficulty obtaining data; lack of reliable information; lack of coordination of studies and lack of qualified labor.	Low	Contract a center of excellence to perform and supervise the analysis and establish TCAs with institutions that can provide reliable data (Inpe, Cepel, EPE, ANA, CPRM, HPP concessionaires).
1.4 Statistical and econometric data analysis, with corrections of gaps in the data series	Technical risk	Data analysis errors.	Low	Supervision and technical coordination of activities by a specialist and validation of statistical and econometric analysis by an external specialist.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
2.1 Definition of spatial restrictions on the installation of floating solar plants in HPP reservoirs	Technical risk	Risk of not validating the methodology.	Low	Establish TCA with institutions that can validate the methodology in the national context (EPE, ANA) or contract a specialist to validate the methodology.
2.2 Definition and validation of methodology, criteria and limits				
2.3 Inclusion of data collected in the geographic information system for preliminary mapping of reservoirs according to the premises and basic restrictions defined	Technical risk	Geoprocessing errors.	Low	Supervision and technical coordination of activities by a specialist.
2.4 Selection of five promising reservoirs for determining the solar resource	Technical risk and institutional risk	Risk of biased and contested selection of reservoirs.	Low	Validate the selection in a workshop with technicians from institutions with recognized technical expertise in the area.
3.1 Installation of solarimeter buoys to measure the solar resource in selected reservoirs	Technical risk	Technical problems or damage to measuring instruments.	High	Install redundant sensors on the solarimeter buoys. Prior to installing the buoys, establish TCAs with the reservoir concessionaires and local science and technology institutes for monitoring and maintaining the instruments during the measurement period, combined with routine visits by a specialist linked to the project. A budget was foreseen to contract staff under the agreements.
3.2 Simulations with satellite radiative transfer model	Technical risk	Computational limitations of the contracted party.	High	Ensure technical capacity and computational infrastructure to support the modeling with the inclusion of a clause in the modeling consulting contract. Moreover, a budget was foreseen to contract computational resources for on-site and cloud (remote) modeling.
3.3 Generation of data on solarimetric potential in reservoirs from observations on buoys	Technical risk	Risk of inconsistent results from measurements and modeling, resulting in errors in solarimetric potential calculations.	Medium	Critically analyze the results, ensuring that aspects of the local resource (derived from the secondary data collected) are taken into account in the analysis (dirt, shading, interactions with the environment etc.). This activity should be validated by the contracted specialist.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
4.1 Reservoir mapping and topographic study of the surroundings 4.2 Elaboration of the bathymetric profile, including reservoir water level variations 4.3 Analysis of the soil profile on the bottom and banks of the reservoirs 4.4 Analysis of access to the grid and power capacity of substations	Technical risk and organizational risk	Errors or inconsistencies in data collection. Difficulty obtaining available information.	Medium	Ensure that the service providers understand the project and its data needs through specialized technical supervision. Establish TCAs with institutions to obtain available data on reservoirs and validate the data collected (ANA, HPP concessionaires, Ibama, state environmental agencies, Aneel, CPRM). Finally, a specialist should be contracted to prepare a Terms of Reference for contracting and validate the results of the activities.
4.5 Preliminary socio-environmental analysis of the reservoirs	Technical risk, organizational risk and institutional risk	Difficulty obtaining available socio-environmental data. Lack of environmental regulatory framework and clear use rights, with the risk that the methodology and data may not be applicable in future projects due to changes	Medium	Establish TCAs with institutions to obtain available socio-environmental data on the reservoirs and validate the data collected. Ensure alignment with regulatory and environmental institutions. Finally, a specialist should be hired to facilitate obtaining socio-environmental data and propose instruments to mitigate regulatory and use rights risks.
5.1 Cross referencing of the data collected with geoprocessing on the selected reservoirs with the spatial restrictions defined in the methodology	Technical risk	Risk of data analysis errors.	Low	Supervision and technical coordination of data processing activities by a specialist.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
5.2 Definition of the areas available for installing floating solar plants in each selected reservoir	Institutional risk	Due to the current lack of an environmental regulatory framework and clear use rights, there is a risk that the methodology may not be applicable for determining available areas for projects due to changes in restrictions, the granting of licenses, concessions etc.	High	Validation and alignment of the methodology to define available areas according to the requirements of regulatory and environmental agencies. A specialist should be contracted to propose instruments to mitigate regulatory and use rights risks.
5.3 Development of pre-project according to the specifications of the selected reservoirs and estimated project costs	Technical risk and institutional risk	Difficulty in obtaining information and temporal evolution of technological parameters. Risk of errors in the estimates of logistics costs, infrastructural costs (anchoring system) and the benefits (evaporation, complementarity) of the technology. Risk of lack of institutional support for the dissemination of the energy source.	Low	Establish TCAs with institutions and floating solar project companies to obtain and validate data. Align pre-project guidelines with electricity sector parameters and national energy planning. Finally, ensure technical coordination of activities.
5.4 Calculation of solar generation potential in selected reservoirs	Technical risk	Risks of errors in estimating the potential.	Low	Supervision and technical coordination of activities by a specialist.

continues

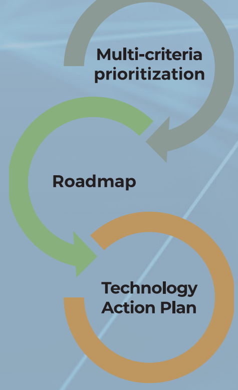
continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
6.1 Elaboration of texts, layout and translation of the inventory	Technical risk and organizational risk	Risk of lack of platform user accessibility. Risk of not reaching the target group (users). Risk of delays in preparing the inventory.	Low	Technical supervision to ensure compliance with deadlines for the preparation and translation of the inventory. Validate the use of the platform with potential users. Apply mechanisms to disseminate results that reach public agents, industry and society. Develop, implement and monitor a communication plan to reach the target users of the inventory.
6.2 Creation of an interactive digital platform with the database and final inventory results				
6.3 Transfer of the platform to a federal research institute, EPE or Aneel	Organizational risk	Lack of interest in hosting the platform by potential partners.	Low	Establish a contract for transferring the platform and TCA with the Ministry responsible for the institution, aimed at hosting and maintaining the platform after the project is completed.

Source: the author.

2.

Technology Action Plan **for Flex Hybrid Vehicles**



2. TECHNOLOGY ACTION PLAN FOR FLEX HYBRID VEHICLES

2.1. Definition of technology

Hybrid vehicles (cars, buses or trucks) contain an internal combustion engine and an electric motor. They use these motors in series, using the combustion engine to generate electricity for the electric motor, or in parallel, used together when necessary or at low revolutions, such as in traffic (DENTON, 2016). They can also vary in electrification levels and can be equipped with a simple start-stop system, which allows the engine to be turned off when the vehicle is stopped, or the sole use of the electric motor to power the vehicle.

In Brazil, the sale of hybrid and electric vehicles grew by approximately 21% between 2017 and 2018 (ANFAVEA, 2019). In 2019, new models were introduced in the Brazilian market, such as Volvo's XC60, Toyota's RAV4 and flex hybrid Corolla, which is considered the first hybrid flex model to be sold by a major automaker in the world (MUNOZ, 2018; IZO, 2019).

Flex hybrid vehicles are based on the same concept as conventional hybrids, but they use a flex engine as an internal combustion engine. That is, they can use gasoline or ethanol, or both mixed together in any ratio. In addition to the advantage of fuel consumption reduction with combined use of an internal combustion engine and an electric motor, there is also a reduction in GHG emissions compared to gasoline, ethanol or diesel vehicles (SAMARAS; MEISTERLING, 2008; HELMS et al., 2010; LAJUNEN; LIPMAN, 2016). On the other hand, it is important to mention that hybrid vehicles have high voltage electrical components (compared to conventional vehicles) and involve greater risks in their maintenance and use.

In the case of flex hybrid buses, there are additional advantages, such as: i) reductions in fuel consumption per kilometer traveled; ii) ability to use more than one type of fuel; iii) less polluting than the conventional diesel buses used in the Brazilian fleet; iv) and high penetration power in urban centers (LAJUNEN; LIPMAN, 2016).

2.2. Scope and goals

The scope of the TAP for flex hybrid vehicles is the development of flex hybrid buses, with the goal of developing the equipment and technology on a national level to address the barriers to its diffusion in Brazil, such as the high cost to enter the market. The goal is to develop a pilot implementation of a flex hybrid bus fleet for a municipal bus line by 2030.

Table 11 – TAP scope and goals

SCOPE	GOALS
Develop flex hybrid bus technology.	Develop a pilot application of a flex hybrid bus fleet for a municipal line by 2030.

Source: the author.

2.3. Actions and activities

Critical gaps and barriers and means to overcome them

The TAP aims to expand the use of flex hybrid bus technology in Brazil; a goal that was defined based on the identification of critical gaps and barriers in the technology chain. With the support of industry researchers and analysts, a critical priority gap was selected for the action plan: the integration of components in vehicles, which is the main technological challenge in the assembly of flex hybrid vehicles.

Achieving the goal of this TAP involves the transition from a technology readiness level of laboratory validation of the integration of vehicle components (TRL4) to the testing of the system prototype in an operational environment, which would allow for the production of components on a commercial scale (TRL 7). More than this, it would overcome barriers, such as the lack of national technological content, the high investment costs for automakers to produce the hybridization kit components, and the lack of technological standards.

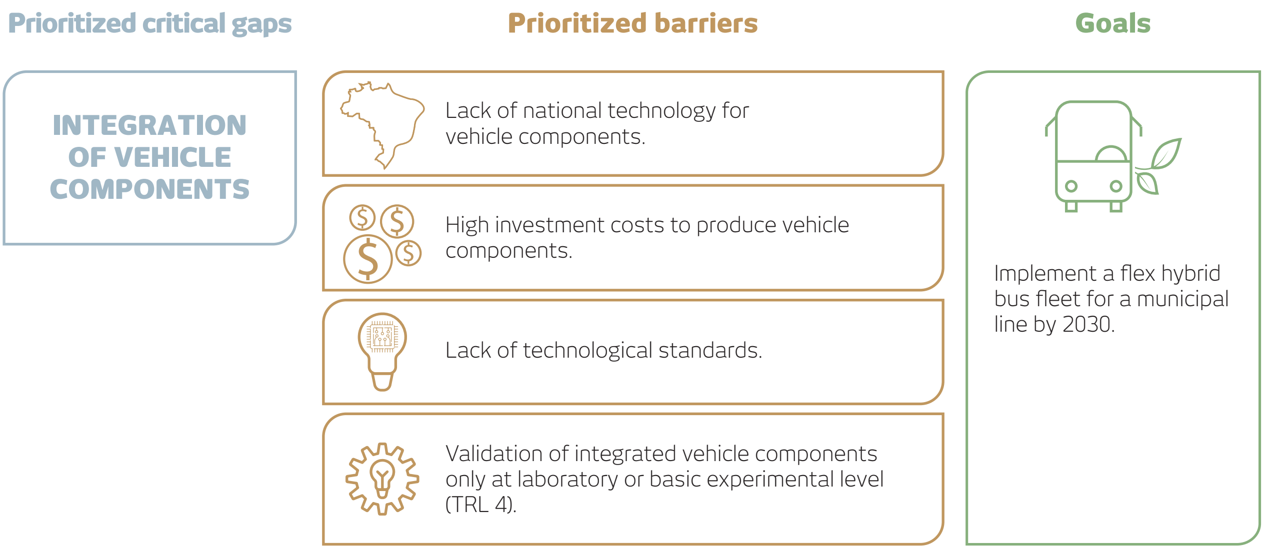


Figure 5 – Critical gaps and barriers and priority goals

Source: the author.

Thus, the goal of the Plan is the implementation of a pilot line of flex hybrid buses to address the prioritized barriers. The following presents the actions and activities required to achieve this objective.

Actions and activities

The TAP is divided into seven actions, with their respective activities, and include: the evaluation and selection of a municipality for the pilot implementation of the flex hybrid bus fleet; the selection and simulation testing of the specifications and equipment for the flex hybrid buses; the creation of a startup for the development and installation of retrofit kits to transform buses to flex hybrid; the pilot application of a fleet of flex hybrid buses with demonstration, data collection and dissemination of results; and the training of qualified labor for the operation and maintenance of these vehicles.

In the following, we present the actions and activities required to implement the pilot flex hybrid bus fleet.

Action 1 and related activities

Action 1 aims to evaluate and select a municipality for the implementation of a pilot application of flex hybrid buses. To achieve this, eight activities were proposed

In order to support the implementation and monitoring of the fleet of flex hybrid buses, a project team should be contracted, as described in sub-activity 1.1. This team will be responsible for mapping and selecting the municipality for implementing the pilot fleet, as well as defining the bus hybridization type and basic specifications, in addition to simulating its operation. Its other role is assisting in the creation of a startup to develop and install retrofit kits in used buses, as well as supporting the implementation of the pilot fleet. In addition, the team will participate in the demonstration, data collection and dissemination of the results, as well as participating in training for the maintenance and operation of the fleet.

The contracted team's first activity is the mapping of potential Brazilian municipalities for the implementation of the pilot line of flex hybrid buses, taking into account criteria such as proximity to automotive research centers, available incentives for the implementation of a pilot line, availability of ethanol and potential partner entities to implement and operate the line.

With the list of municipalities in sub-activity 1.2, the proximity to automotive research centers that could assist in the testing and monitoring of the fleet should be evaluated. Available incentives for the implementation of the pilot line should also be considered, including tax incentives and subsidies. It is also necessary to assess the local infrastructure for supplying fuel for hybrid flex buses. Finally, potential local partner entities for the implementation and operation of the pilot line of flex hybrid buses should be assessed. These activities are part of sub-activities 1.3, 1.4 and 1.5.

Sub-activity 1.6 involves an analysis based on the evaluated criteria using a multi-criteria analysis to select a municipality for the implementation of the pilot line of flex hybrid buses.

To encourage cooperation in the TAP, a governance body should be created with the participation of key stakeholders, as proposed in sub-activity 1.7. These stakeholders should monitor and plan the project activities to anticipate obstacles and prepare actions to address them, seeking to determine stakeholder responsibilities and reduce risks in the activities.

Sub-activity 1.8, the final activity in this action, aims to establish partnerships with research centers, public authorities and bus dealerships in the municipality selected for the pilot application, aimed at assisting in the implementation of the flex hybrid bus fleet. These partnerships should be formalized through TCAs between the parties, aimed at ensuring the sustainability of the TAP. This requires contracting legal support to prepare and monitor compliance with the agreement.

Table 12 – Action 1 and related activities

ACTION 1 – EVALUATION AND SELECTION OF A MUNICIPALITY FOR THE IMPLEMENTATION OF THE PILOT APPLICATION OF FLEX HYBRID BUSES	
Sub-activity 1.1	Prepare Terms of Reference and contract team to evaluate, assist and monitor the implementation of a pilot fleet of flex hybrid buses in a Brazilian municipality
Sub-activity 1.2	Map potential Brazilian municipalities for the implementation of the pilot line of hybrid flex buses, based on a multi-criteria analysis, such as the proximity to automotive sector industries and companies and available incentives for the implementation of the pilot line
Sub-activity 1.3	With the list of mapped municipalities, evaluate the proximity to automotive research centers for future testing and monitoring
Sub-activity 1.4	With the list of mapped municipalities, assess available incentives for the implementation of the pilot line and the availability of fuel (ethanol and gasoline) for the fleet
Sub-activity 1.5	With the list of mapped municipalities, determine potential partner entities for the implementation and operation of the pilot hybrid flex bus line
Sub-activity 1.6	Select the location for the implementation of the pilot line based on the evaluated criteria
Sub-activity 1.7	Creation of a governance body with the participation of key stakeholders
Sub-activity 1.8	Establish partnerships with research centers, public authorities and bus dealerships in the selected location for the implementation of the flex hybrid bus fleet

Source: the author.

Action 2 and related activities

Action 2 involves five activities related to the selection of specifications, equipment and simulating the operation of the pilot fleet of flex hybrid buses.

Sub-activity 2.1 involves the definition of the flex hybridization method to be used to retrofit buses, considering the level and type of hybridization, assessing the differences between micro and total hybridization and series, parallel or series-parallel hybridization. In this activity, safety, environmental, autonomy and operational criteria should also be considered in defining the type of hybridization. These selection criteria are aimed at maximizing the co-benefits of the pilot application of flex hybrid buses.

Subsequently, the basic specifications of the hybrid flex buses should be defined, such as number of seats, height of the bus door, vehicle weight and passenger access, in accordance with local legislation. Fuel capacity should also be estimated, considering the potential routes for the fleet.

Based on the specifications determined in sub-activity 2.1, sub-activity 2.3 specifies the chassis, motor/generator, batteries and other necessary equipment to adapt buses to flex hybrid, including cables and connectors.

Sub-activity 2.4 is a necessary step prior to simulating the operation of the selected hybrid flex bus type. To perform the simulation, it is necessary to determine the driving cycles of the buses in the selected municipality, as well as the fuel consumption of the buses, for comparisons with the simulated operation.

From the specifications selected in sub-activities 2.1, 2.2 and 2.3, together with the data collected in sub-activity 2.4, it is possible to simulate the operation of the flex hybrid buses. Thus, sub-activity 2.5 uses simulation tools to make any necessary modifications to the defined configurations, as well as simulating the operation of the flex hybrid buses.

Table 13 – Action 2 and related activities

ACTION 2 – SELECTION OF SPECIFICATIONS AND EQUIPMENT AND SIMULATING OPERATION OF THE PILOT FLEET OF FLEX HYBRID BUSES	
Sub-activity 2.1	Define the hybridization type for the flex hybrid buses
Sub-activity 2.2	Definition of basic specifications of the buses to be assembled, such as number of seats, passenger access and fuel capacity, in accordance with local legislation
Sub-activity 2.3	With the selected specifications, define the chassis, the electric motor/generator, batteries and any necessary equipment for adapting the buses to flex hybrid
Sub-activity 2.4	Compile data on the fleet, fuel consumption and driving cycles in the municipality where the pilot fleet will be implemented
Sub-activity 2.5	With the data and selected equipment, simulate the operation of the hybrid flex bus using an adequate driving cycle for the bus line

Source: the author.

Action 3 and related activities

After selecting the municipality for the implementation of the fleet and simulating its operation, Action 3 involves activities to create a startup for developing and installing retrofit kits in used buses for conversion to flex hybrid. This action contains four activities related to the Integrated Transport System (ITS).

Sub-activity 3.1 involves defining the mission and objectives of the startup for installing flex hybrid retrofit kits in used buses. With these definitions, the stakeholders, institutions and companies can be identified for potential partnerships with the ITS, considering potential contributions over the course of the project and assisting in the TAP actions (sub-activity 3.2).

Sub-activity 3.3 involves the elaboration of a public notice for the selection of proposals to constitute the ITS, which should contain the requirements of the incubator where the system will be installed. With the public notice, sub-activity 3.4 seeks to formalize partnership agreements, stipulating the rights and obligations of the parties for the establishment of the ITS. Finally, sub-activity 3.5 consists of the establishment of the ITS in a business incubator for both the production of the hybridization kit for buses and the installation of the kits in the pilot fleet.

Table 14 – Action 3 and related activities

ACTION 3 – CREATION OF A STARTUP TO DEVELOP AND INSTALL RETROFIT KITS IN USED BUSES FOR FLEX HYBRID CONVERSION	
Sub-activity 3.1	Define mission and objectives for the startup to be created and considered as the ITS, with a focus on developing retrofit kits to convert used buses to flex hybrid
Sub-activity 3.2	Identify stakeholders, institutions and companies for potential partnerships aimed at implementing the ITS
Sub-activity 3.3	Publish a public notice for proposals for the ITS, according to the requirements of a business incubator
Sub-activity 3.4	Select partner and formalize agreement to establish the ITS
Sub-activity 3.5	Establish the ITS in a business incubator to design, build and install the hybridization kits

Source: the author.

Action 4 and related activities

Action 4 involves the elaboration of the design for equipment and the hybridization kit to convert a fleet of diesel buses to flex hybrid. The six related activities range from the planning and design of the retrofit kit equipment to its production. This is the most cost-intensive action, as it requires the acquisition of the equipment to produce the hybridization kit.

It is necessary to plan the creation of the hybridization kit based on the specifications selected by the project technical team in Actions 1 and 2, in conjunction with the ITS. This planning is followed by the equipment design and schematic for the production of the kits and the selection of the equipment to be purchased, considering possible adaptations for their future installation in buses (sub-activities 4.1, 4.2 and 4.3).

Sub-activity 4.4 involves the purchasing of the necessary items for the production of ten hybridization kits, after a prior analysis of possible equipment incompatibilities. With the purchased items, the equipment for the hybridization kit is built and adapted, considering the stages and the schematic of the project. Finally, in sub-activity 4.6, the hybridization kits are produced using the established definitions.

Table 15 – Action 4 and related activities

ACTION 4 – ELABORATION OF THE EQUIPMENT AND HYBRIDIZATION KIT DESIGN FOR CONVERTING A FLEET OF DIESEL BUSES TO FLEX HYBRID	
Sub-activity 4.1	Plan the creation of the hybridization kit based on the specifications and equipment determined in Actions 1 and 2
Sub-activity 4.2	Determine the necessary equipment for the production of the hybridization kit
Sub-activity 4.3	Select equipment available on the market for direct use or adaptation in the hybridization kit
Sub-activity 4.4	Purchase of selected equipment for the production of ten hybridization kits
Sub-activity 4.5	Construction and adaptation of equipment for assembling the hybridization kit based on the definitions established in the project
Sub-activity 4.6	Production of the hybridization kit with the purchased equipment

Source: the author.

Action 5 and related activities

Action 5 is the pilot application of the flex hybrid bus fleet. This action involves two activities for the installation of the hybridization kit and the start of fleet operations.

In sub-activity 5.1, the hybridization kits are installed in the fleet of buses, along with the necessary sensors for data collection for subsequent dissemination, in conjunction with the partnerships established in sub-activity 1.7.

After the installation of the hybridization kits, the ten hybrid flex buses can begin operating on a bus line in the selected municipality, in conjunction with the ITS, the project technical and governance teams and partner bus dealerships.

Table 16 – Action 5 and related activities

ACTION 5 – PILOT APPLICATION OF FLEX HYBRID BUSES IN A BRAZILIAN MUNICIPALITY	
Sub-activity 5.1	Installation of hybridization kits in a fleet of buses, along with sensors for data collection (according to partnership agreement established in sub-activity 1.8)
Sub-activity 5.2	Start of operations of the pilot fleet of ten flex hybrid buses

Source: the author.

Action 6 and related activities

With the start of operations of the flex hybrid bus fleet, the fleet should be monitored for subsequent dissemination of results (as determined in the Action 6 activities).

In sub-activity 6.1, the fleet of flex hybrid buses is monitored by the project technical and governance teams in conjunction with the partner bus dealerships to collect data for future dissemination and for potential improvements of the hybridization kit equipment. In addition, the necessary legal data should be collected to approve the flex hybrid bus technology, including certifications from Inmetro and the Vehicle Safety and Environmental Technical Inspection Norm, among other instruments.

Subsequently, sub-activity 6.2 involves the dissemination of the relevant data from the pilot fleet demonstration on the website and in publications. This activity seeks to disseminate the benefits of the technology to foster the development and diffusion of the technology at the national level.

Table 17 – Action 6 and related activities

ACTION 6 – DEMONSTRATION AND DATA COLLECTION ON THE FLEX HYBRID BUS FLEET, WITH SUBSEQUENT DISSEMINATION OF RESULTS	
Sub-activity 6.1	Monitor the operation of the hybrid flex bus fleet, with data collection for potential hybridization kit improvements, in addition to producing a report with the legal data necessary to approve the technology for implementation at the national level
Sub-activity 6.2	Disseminate the results of the implementation of the pilot fleet of flex hybrid buses on websites and in publications

Source: the author.

Action 7 and related activities

Finally, Action 7, which is related to the previous activities, involves training for the maintenance and operation of the flex hybrid bus fleet.

Sub-activities 7.1 and 7.2 include the development and realization of training courses for the maintenance and operation of the pilot fleet of flex hybrid buses. These activities are necessary due to the specificities of hybrid technology, which require specialized labor at bus dealerships.

Table 18 – Action 7 and related activities

ACTION 7 – TRAINING FOR THE MAINTENANCE AND OPERATION OF THE FLEX HYBRID BUS FLEET	
Sub-activity 7.1	Development and realization of training courses to maintain the pilot fleet of flex hybrid buses
Sub-activity 7.2	Development and realization of training courses to operate the pilot fleet of flex hybrid buses

Source: the author.

2.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

The mobilization of multiple stakeholders in different segments ensures greater cooperation between stakeholders and authorities for the success of the Plan. Thus, we highlighted different stakeholders from the public and private sectors, as well as associations and representative entities to collaborate in the implementation of the TAP.

To coordinate the Plan, some institutions with the necessary expertise to carry out the actions described above can be highlighted. Itaipu Binacional, with its extensive portfolio of electric vehicle, electric plane and ethanol hybrid bus projects, is a potential partner to coordinate the TAP. It should be emphasized that the institution responsible for coordination should establish a permanent technical team for carrying out actions and activities, assisting in the creation of the ITS and the implementation, dissemination and training related to the pilot application.

For governance, we can highlight key stakeholders such as the CNT, ANP, Anfavea, NTU, bus dealerships and the ITS. In terms of resource mobilization and potential financing for the TAP, we suggest the ME, Finep, BNDES, CNPq and Embrapii. Other potential technical partners and target group for the dissemination and training activities can be highlighted: teaching and research institutions with expertise in the area; the Leopoldo Américo Miguez de Mello Research Center (Cenpes); business incubators; and bus dealerships.

Table 19 – Main stakeholders to involve in the implementation of the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Itaipu Binacional	Itaipu is active in the production and dissemination of scientific and technological knowledge in Brazil and Paraguay, in partnership with the Itaipu Technological Park (PTI). In collaboration with public and private educational and research institutions, it has developed a number of initiatives, contributing to entrepreneurship and the generation of jobs and income in the region. It has extensive experience from different projects, such as electric vehicle, electric plane and hybrid bus projects. It could act in the coordination of the TAP.
CNT	The mission of the National Transport Commission (CNT) is to support, develop and represent the transport and logistics sector. It could act as an institutional governance partner for entering into partnership agreements and for monitoring training actions.
ANP	The National Petroleum, Natural Gas and Biofuels Agency (ANP) is the federal agency responsible for regulating the oil and natural gas and biofuels industries in Brazil. It would be responsible for granting the license and monitoring the operation of the fleet.
Anfavea	The National Association of Motor Vehicle Manufacturers (Anfavea) is the entity that brings together vehicle (automobiles, light commercial vehicles, trucks and buses), self-propelled agricultural and road machinery (wheel and crawler tractors, harvesters and backhoes) manufacturers and industrial and production facilities in Brazil. It could be part of the TAP governance structure.
NTU	The National Association of Urban Transport Companies (NTU) is a national sectoral entity whose main objective is representing the operators of urban and metropolitan bus lines in government and civil society matters. It could be part of the TAP governance structure.
Bus dealerships	They could be technical partners for TAP activities, as well as being the target group for dissemination and training activities. In addition, they could be part of the TAP governance structure.
ITS	The Integrated Transport System (ITS) is a company to be created (or be in the initial stage of creation) that, ideally, will be incubated in a business incubator close to the location where the fleet of flex hybrid buses is implemented. The objective of this company is to design and install retrofit kits in buses to convert them to flex hybrid.

continues

continuation

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
ME	The Ministry of Economy is responsible for the formulation and execution of the national economic policy and the financial administration of the State. It is responsible for the preparation of the public notice for the sub-project for the implementation of the pilot fleet of flex hybrid buses.
Finep	The Financier of Studies and Projects promotes science, technology and innovation in companies, universities, technological institutes and other public and private institutions. It participates throughout the innovation chain, focusing on strategic, structural and impact actions for the sustainable development of Brazil. It could act as a financing agency for TAP activities.
BNDES	The development bank is the main instrument of the Federal Government for long-term financing and investment in all segments of the Brazilian economy. It could act as a financing agency for TAP activities.
CNPq	CNPq promotes and fosters scientific and technological development in Brazil and contributes to the formulation of national science and technology policies. It could support the promotion of TAP activities.
Embrapii	Embrapii provides support for technological research institutions to carry out technology research development projects for innovation, in cooperation with companies in the industrial sector. It could play a role in activities to promote the TAP.
Cenpes	The Leopoldo Américo Miguez de Mello Research Center (Cenpes) is the Petrobras unit responsible for research and development activities and has one of the largest energy industry applied research complexes in the world. It works with strategic choices with a technological focus in the area of efficient energy use and the transition to a low carbon energy matrix. It could act as a technical partner and target group for the training and dissemination activities.
Educational and research institutions	They could act as technical partners with expertise within the scope of the TAP. In particular, they could conduct the Action 7 training activities, as well as provide qualified labor for the TAP permanent team.
Business Incubator	It could be responsible for incubating the ITS startup.

Source: the author.

Schedule of actions and activities

The time frame for implementing the action plan is eight years, a time believed adequate and sufficient for technical and financial preparations and the implementation of the TAP activities.

Some activities may occur concurrently, as some of the activities of Actions 1 and 2 for selecting the municipality and defining the bus specifications. Sub-activity 1.7 should occur over almost the entire TAP implementation period, as it reduces project risk. Some of the Action 6 and 7 activities occur simultaneously, and this is due to the need for training courses for maintaining and operating the flex hybrid bus fleet.

Sub-activities 5.1 and 5.2 should occur independently, as they are critical activities for the conclusion of the TAP, with high risks associated with the assembly and initial operation of the pilot bus fleet.

Table 20 – TAP implementation schedule

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
1.1	■																	
1.2		■																
1.3		■																
1.4		■																
1.5		■																
1.6		■	■															
1.7			■	■	■	■	■	■	■	■	■	■	■	■	■	■		
1.8			■	■														
2.1					■													
2.2					■													
2.3					■													
2.4					■													
2.5					■	■												
3.1						■												
3.2						■												
3.3							■											
3.4							■											
3.5								■										
4.1								■										
4.2									■									
4.3									■									
4.4									■									
4.5										■								
4.6										■								
5.1											■							
5.2												■						
6.1													■	■	■	■		
6.2															■	■		
7.1													■	■	■	■		
7.2												■	■	■	■			

Source: the author.

2.5. TAP implementation costs and financing options

After describing the actions, activities and potential stakeholders to mobilize, figure 6 shows the share of each action in the estimated total cost. The total cost was estimated at approximately BRL 8.3 million. Action 4, which involves the design and assembly of the hybridization kits, as well as the acquisition of the necessary equipment to build them, accounts for approximately 54% of the total project cost.

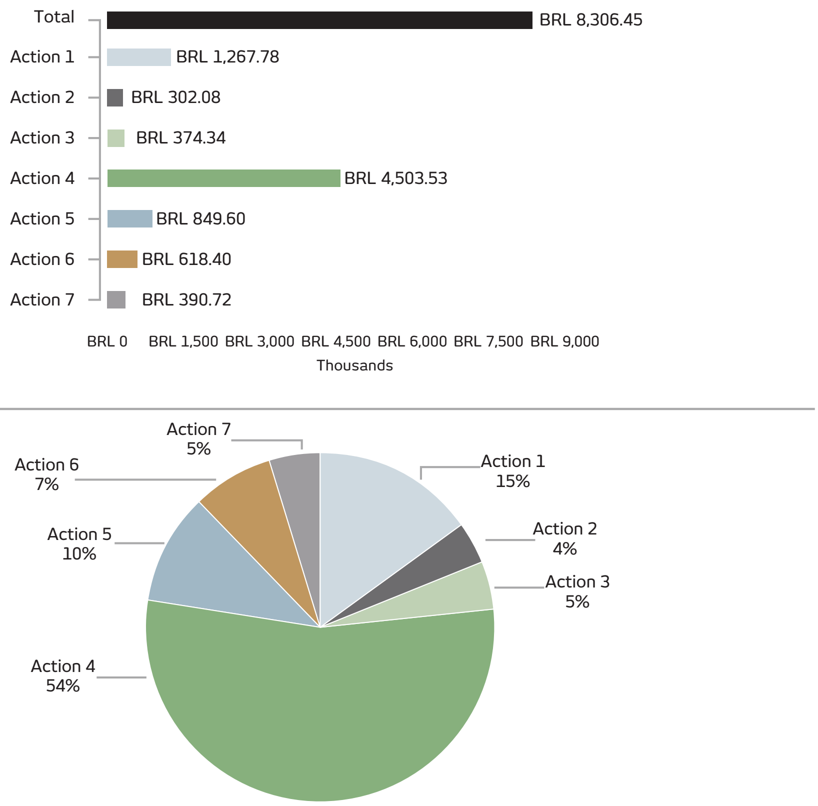


Figure 6 – Total costs, per action, in thousands of BRL and as a percentage, for the flex hybrid vehicle TAP

Source: the author.

With respect to potential sources of financing for the activities, and with a view to financial results and the scope of Actions 1, 2 and 7, we determined the typical means of financing would be non-repayable loans and technical assistance. Financing is accessible for state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives.

The action to create the startup could be financed with non-repayable loans and assistance, as well as corporate participation in the form of private equity or venture capital. With this kind of financing, investors have a direct shareholding in organizations and, with this financial contribution, these organizations can expand and modernize their operations. This financing is accessible for small, medium and large companies, with the possibility to access five mechanisms. Finally, Actions 4 to 6 can access repayable loans.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and in the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b).

2.6. Risk and contingency plan

We analyzed the potential risks involved to implement the TAP activities. The following risk categories were considered: political, institutional, organizational, technical and cost risks. They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs). Finally, contingency actions were proposed to mitigate these risks.

The highest risks are associated with sub-activities 4.4, 4.5, 4.6 and 5.1. These risks are associated with potential incompatibilities of the equipment purchased for the hybridization kit and the risk of currency exchange rate variations, which could make it impossible to purchase these items. There is also the risk of incompatibilities between the hybridization kit and the bus to be retrofitted; risk of non-compliance with the partnership agreement signed in sub-activity 1.8; delays in delivery of the kit assembly; and lack of technical coordination in sub-activity 5.1.

In order to limit these high risks, potential incompatibilities of the selected equipment can be mitigated with 3D computer-aided design software, in addition to establishing mechanisms in the project contracting to ensure contingency resources in the case of variations in equipment costs. In the case of sub-activity 5.1, rights and obligations should be established in the partnership agreement, addressing installation costs by the bus dealership and maintenance of the buses after the conclusion of the project.

Table 21 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1 Elaborate Terms of Reference and contract team to evaluate, assist and monitor the implementation of a pilot fleet of flex hybrid buses in a Brazilian municipality	Technical risk and organizational risk	Risks associated with the selection of the research group, given the lack of similar projects in Brazil, which could make it difficult to carry out and coordinate the project activities.	Low	Initially, a technical coordinator for the project should be contracted to prepare the Terms of Reference and contract a multidisciplinary research team with experience in the area of flex hybrid bus technology. These specialists should come from universities and research centers with expertise in the area.

continues

continuation

<table>
<tr><th rowspan="2">SUB-ACTIVITIES</th><th colspan="4">RISK AND CONTINGENCY PLAN</th></tr>
<tr><th>Risk category</th><th>Description of risk</th><th>Risk assessment</th><th>Contingency actions</th></tr>
<tr><td>1.2 Map potential Brazilian municipalities for the implementation of the pilot line of flex hybrid buses using a multi-criteria analysis, such as the proximity to automotive sector industries and companies and available incentives for the implementation of the pilot line</td><td rowspan="5">Technical risk, institutional risk and organizational risk</td><td rowspan="5">Risk of human errors in data collection and analysis. Lack of stakeholder interest in participating in the multi-criteria analysis. Delays in completing activities.</td><td rowspan="5">Low</td><td rowspan="5">Contract project managers to review and coordinate the documents generated to ensure greater reliability in the collected data. In addition, stakeholders should be mobilized to participate in a workshop to apply the multi-criteria methodology. Finally, deadlines should be monitored to mitigate any delays in completing activities.</td></tr>
<tr><td>1.3 With the list of mapped municipalities, evaluate the proximity to automotive research centers for future testing and monitoring</td></tr>
<tr><td>1.4 With the list of mapped municipalities, assess available incentives for the implementation of the pilot line and the availability of fuel (ethanol and gasoline) for the fleet</td></tr>
<tr><td>1.5 With the list of mapped municipalities, evaluate potential partner entities for the implementation and operation of a pilot line of flex hybrid buses</td></tr>
<tr><td>1.6 Determine the municipality for the implementation of the pilot line based on the evaluated criteria</td></tr>
<tr><td>1.7 Creation of a governance group with the participation of key stakeholders</td><td>Technical risk and organizational risk</td><td>Risk of inadequate monitoring and the ability to anticipate possible future actions.</td><td>Low</td><td>Contract a risk analysis specialist with experience in long-term projects.</td></tr>
</table>

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.8 Establish partnerships with research centers, public authorities and bus dealerships in the selected location for the implementation of the flex hybrid bus fleet	Organizational risk and political risk	Risk of delays in the procedure to establish partnerships. Risk of lack of stakeholder interest and institutional involvement.	Medium	In parallel to the previous phases, ascertain the willingness of local stakeholders to enter into partnerships for the duration of the project. Establish partnerships with more than one group at the same time. In addition, TCAs should be drawn up between the parties that establish benefits and obligations.
2.1 Define the type of hybridization for the flex hybrid buses	Technical risk and organizational risk	Risk of incompatibilities when adapting equipment and/or in the vehicles. Lack of qualified labor to carry out the activities. Lack of coordination and delays in the delivery of activities.	Medium	Defining the type of hybridization and the basic specifications of the bus and equipment in simulations to ensure better analysis of the data and mitigate possible incompatibilities. Contract labor from leading centers, with supervision and meticulous planning of activities by the technical coordination of the project.
2.2 Define basic bus specifications, such as number of seats, passenger access and estimate of fuel capacity, in accordance with local legislation				
2.3 With the specifications, specify the chassis, the electric motor/generator, batteries and necessary equipment for the assembly of the pilot fleet of flex hybrid buses				
2.4 Data collection on fleet, fuel consumption and driving cycles in the municipality where the pilot fleet will be implemented		Difficulty obtaining data. Lack of coordination and delays in the delivery of activities.	Low	In parallel with the previous activities, determine the availability of the necessary data to carry out the analysis to mitigate the risk of insufficient data. Ensure supervision and thorough planning of activities by the technical coordination of the project.
2.5 With the data and selected equipment, simulate the operation of the hybrid flex buses using an appropriate driving cycle for the bus line		Lack of qualified labor to carry out the activity. Delays in the delivery of previous activities. Errors in the driving cycle estimates.		Ensure supervision and thorough planning of activities by the technical coordination of the project and on-site monitoring of the driving cycle simulations by team members.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
3.1 Define mission and objectives for the startup to be created, with a focus on designing kits to retrofit buses to flex hybrid	Technical risk	Failure to define the ITS mission and objectives.	Low	Use different project management methodologies to validate the ITS.
3.2 Identify stakeholders, institutions and companies for potential partnerships aimed at implementing the ITS	Organizational risk	Risk of not identifying stakeholders, institutions and companies capable of collaborating in the implementation of the ITS.	Low	Determine stakeholders, institutions and companies that can contribute in a timely manner to the actions to be carried out by the ITS and the elaboration of partnership agreements. Conduct a workshop to map stakeholders.
3.3 Publish a public notice for ITS proposals, according to the requirements of a business incubator	Technical risk and political risk	Risks associated with the creation of a startup with insufficient experience to create the hybridization kit. Bias in the selection due to trying to satisfy the interests of specific groups.	Medium	Ensure the participation of different stakeholders in the elaboration and revision of the public notice to meet the minimum requirements for the creation of the ITS. Avoid possible selection bias by using criteria that favor proven technical expertise. Formalize a partnership agreement with rights and obligations of the parties.
3.4 Select partner and formalize agreement to establish the ITS				
3.5 Establish ITS in a business incubator to design, build and install the hybridization kits	Organizational risk and institutional risk	Lack of stakeholder and incubator support and commitment to establish the ITS.	Low	Establish agreements with guidelines for the stakeholders and institutions involved with the ITS.

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
4.1 Plan the creation of the hybridization kit based on the specifications and equipment listed in Actions 1 and 2	Organizational risk and technical risk	Errors in the planning of the hybridization kit assembly project and lack of skilled labor to carry out the project. Delays in delivering the results of Actions 1 and 2.	Low	Use a trained and experienced team, capable of dealing with the different challenges in creating a pilot application. Ensure the permanence of the technical team involved in Actions 1 and 2, with supervision and commitment to meeting deadlines.
4.2 Determine the necessary equipment for the production of the hybridization kits				
4.3 Select equipment available on the market for direct or adapted use in the hybridization kits	Technical risk	Lack of some necessary equipment in the domestic market for the assembly of the hybridization kits.	Low	Establish international partnerships for the acquisition of the necessary equipment for the assembly of the hybridization kit in case equipment is not available in the domestic market.
4.4 Acquisition of selected equipment for the elaboration of ten hybridization kits	Technical risk and cost risk	Risk of incompatibilities between the equipment purchased to create the hybridization kit. Exchange rate variation risk, given the possibility of purchasing imported components.	High	Determine possible incompatibilities in the selected equipment using 3D computer aided design software. In addition, mechanisms should be established in the project contracting that ensure contingency resources in case of variations in equipment costs.
4.5 Building and adaptation of equipment for assembling the hybridization kit based on the project definitions				
4.6 Produce the hybridization kit using the purchased equipment				

continues

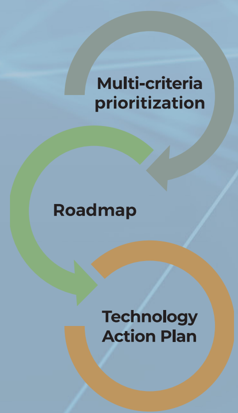
continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
5.1 Install the hybridization kits in the fleet of buses along with the necessary sensors for data collection (according to the partnership agreement established in sub-activity 1.8)	Technical risk, institutional risk and organizational risk	Risk of incompatibilities between the hybridization kit and the bus to retrofit. Risk of non-compliance with the partnership agreement signed in sub-activity 1.8. Delays in delivery of the kit assembly. Lack of technical coordination for the activity.	High	Determine possible incompatibilities in the hybridization kit and the buses to retrofit using 3D computer-aided design software. Establish rights and obligations in the partnership agreement to address installation costs by the bus dealerships and fleet maintenance after the conclusion of the project. Centralize technical coordination in the project team.
5.2 Begin operations of the pilot application of ten flex hybrid buses	Technical risk	Risk of problems in the initiation of fleet operations.	Medium	Assess the skills of contracted parties beforehand (sub-activity 1.7). Use contingency resources to address operational problems.
6.1 Monitor the operation of the fleet of flex hybrid buses, with data collection aimed at potential hybridization kit improvements	Technical risk and institutional risk	Risk of problems in the operation of the fleet and non-compliance in the activities established in the partnership agreement.	Medium	Assess the skills of contracted parties beforehand (sub-activity 1.7). Use contingency resources to address operational problems. Monitor legal advice on compliance with contractual clauses.
6.2 Disseminate the results of the implementation of the pilot fleet of flex hybrid buses on websites and in publications, in addition to creating a report with the legal data necessary to authorize this technology for use nationwide	Technical risk and institutional risk	Lack of human resources to continue collecting data and update sites and publications with data on the flex hybrid bus fleet.	Low	Make collaborators aware of the social benefits of the project and the need to disseminate the data. Contract a technical team and disseminate content and pilot application results on the project website.
7.1 Development and realization of training courses to maintain the pilot fleet of flex hybrid buses	Organizational risk and technical risk	Lack of engagement from the dealership technicians and specialists involved in preparing and teaching the training courses. Difficulty contracting specialized labor.	Low	Make employees aware of the social benefits of the project. Contract specialized technicians for the maintenance and operation of the flex hybrid bus fleet. Establish wage benefits for professionals with satisfactory operation and fleet maintenance times.
7.2 Development and realization of training courses to operate the pilot fleet of flex hybrid buses				

Source: the author.

3.

Technology Action Plan **for Ethanol Fuel Cell Electric Vehicles**



3. TECHNOLOGY ACTION PLAN FOR ETHANOL FUEL CELL ELECTRIC VEHICLES

3.1. Definition of technology

In most cases, fuel cells and their respective stacks have conversion efficiencies superior to conventional combustion or electric generation technologies and emit much lower levels of air pollutants, such as ozone, NOx and particulates (CARRETTE; FRIEDRICH; STIMMING, 2001; GIDDEY et al., 2012; HELLMAN; VAN DEN HOED, 2007).

These energy gains can be up to 60% higher than internal combustion engines (UNITED STATES, 2020). Considering that the life cycle of ethanol (mainly produced from sugar cane in Brazil) is carbon neutral, the potential environmental benefits of ethanol fuel cell vehicles are significant. Casas et al. (2011) corroborate this conclusion with their work on using a fuel cell for electricity co-generation in an ethanol plant, with GHG emission reductions of approximately 50% compared to traditional plants.

There are several types of fuel cells, which can vary both in the configuration of their electrodes and electrolytes and the type of fuel to be electrochemically oxidized. A direct ethanol fuel cell is defined as one in which the anode is supplied with liquid or gaseous ethanol, anhydrous or diluted in water (BADWAL et al., 2015), and the cathode supply is air or oxygen. This term is mainly used to differentiate cells in which the fuel is hydrogen resulting from an external reform, though with a coupled unit using ethanol.

The technology, in general, offers several technical and environmental advantages. They include ease of transportation, distribution, reduced risks and low carbon footprint, which are significant, especially when comparing ethanol to hydrogen and methanol (BADWAL et al., 2015) or socioeconomic, like the guarantee of a captive market for ethanol (mainly in Brazil) once electric engines replace internal combustion engines. Using the same social framework as the sugar-ethanol plants and the entire production and distribution chain, the technology could contribute to the preservation of jobs in the sector.

However, there are several obstacles that hinder the practical application of direct ethanol fuel cells. Using the publications by An, Zhao and Li (2015), Badwal et al. (2015), Kamarudin et al. (2013) and Ong, Kamarudin and Basri (2017) as a basis, the main challenges to overcome are:

- Energy density and operating time below what is required for commercial use, due in part to the slow oxidation kinetics of ethanol in the anodes;
- Cathode catalyst poisoning by smaller compounds, resulting from partial oxidation of ethanol;
- Fuel crossover[2] through the membrane (only for batteries with a proton exchange membrane);
- Carbon deposits in anode catalysts.

Among direct ethanol fuel cells, the most promising technology is solid oxide and, more precisely, one supported by metals, which has higher energy densities, resistance to temperature variation and longer operating times (DOGDIBEGOVIC; FUKUYAMA; TUCKER, 2020). The organization of this type of cell, which uses metallic interconnectors between the cell units, greatly reduces the thickness of the electrolyte, since it is supported by the anode itself. There is no problem of fuel crossover or cathode poisoning, by definition, due to the impermeability of the electrolyte.

[2] Phenomenon that occurs in membrane fuel cells, in which fuel and/or products migrate from one electrode to another, resulting in undesired oxidation reactions in the cell design.

3.2. Scope and goals

The TAP should be executed in two phases, with the development of a prototype in each one. First, the technology is elevated to TRL 5, with laboratory validation in a relevant environment and, finally, to TRL 7, with a complete operational system prototype.

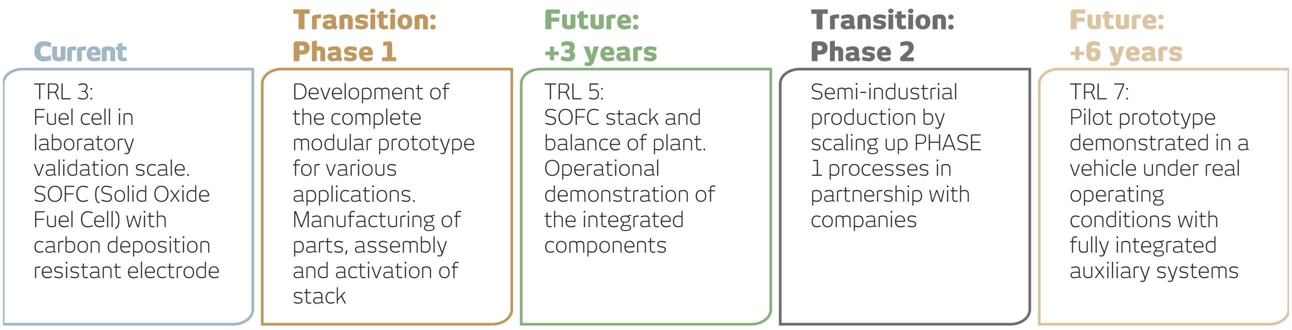


Figure 7 – TAP development phases for ethanol fuel cell vehicles

Source: the author.

It is also understood that the use of direct ethanol fuel cell technology is better for vehicles that are difficult to electrify (as mentioned above). Moreover, there is also the advantage of using Brazil's existing infrastructure for the production, distribution and commercialization of ethanol for vehicles.

The scope of the Plan is the development of the technology for the specific needs of the transport sector, with higher operating temperatures and varied electrical demand, focusing on vehicles that are difficult to electrify. The goal is to raise the technology to TRL 7, demonstrating an operational prototype validated in an environment relevant to industry in Brazil by the year 2030.

Table 22 – TAP scope and goals

SCOPE	GOALS
Develop direct ethanol fuel cell technology for the transport sector.	Transition from technology readiness level three (TRL 3) (conceptual validation) to TRL 7 (demonstration in vehicles), with the engineering and production of a solid oxide ethanol fuel cell.

Source: the author.

3.3. Actions and activities

Critical gaps and barriers and means to overcome them

Starting with the choice of solid oxide fuel cell (SOFC) as the type of direct ethanol fuel cell to be used, the biggest challenge is the development of an anode catalyst capable of simultaneously oxidizing ethanol and smaller matter (which are the result of thermal decomposition) and resisting carbon deposition due to cell activity. There are also lesser challenges, such as the water vapor to fuel ratio, which reduces carbon deposition, but can cause several other problems in anode functioning and sensitivity to traces of sulfur present in ethanol (BADWAL et al., 2015). There are several catalyst options, which can essentially be divided into nickel-based, without nickel, and metal alloys.

Interviews with relevant stakeholders is an important part of this action plan, aimed at validating reported results in the scientific literature. An example is the interview with Professor Paulo Emílio de Miranda, coordinator of the Hydrogen Laboratory at the Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering at the Federal University of Rio de Janeiro (Coppe/UFRJ) and president of the Brazilian Hydrogen Association, where Brazil has attained world renown in the development of SOFCs, overcoming some of the challenges cited in the literature, and attaining a technology readiness level between 3 and 4.[3]

This level of maturity is borne out in the patents in Miranda (2007), Miranda, Venancio and Miranda (2016) and Miranda and Icardi (2017), which demonstrate, respectively: i) processes for making electrodes for SOFCs that are resistant to carbon deposition, as also described in Sarruf et al. (2020) and Venâncio and Miranda (2017); ii) a fuel cell testing system allowing the use of carbonaceous fuels, such as ethanol, without electrode carbon deposition; and iii) oxidation methods for ethanol and compounds resulting from the thermal reforming of alcohol with or without water. There are also patents that could overcome potential challenges to applying the technology in electric vehicles with energy storage and a smart generator (MIRANDA; CARREIRA, 2016; MIRANDA; TORRES, 2011).

Achieving the TAP goals would overcome the main technological barriers to the maturity and diffusion of the technology on a commercial scale. Among the barriers, we can cite:

- Lack of consensus on the optimal direct ethanol fuel cell technology for operating at high capacity and long periods, and with thermal stability;
- Low technology readiness level, that may or may not improve. This underscores the need to support research for development and testing in order to demonstrate the viability of the technology;
- The production of the technology occurs only at the research level and requires further development for future diffusion in the market, in addition to depending directly on development in the international market. The technology does not exploit the country's competitive advantages (such as hydrogen).

As previously stated, the priority of this TAP is to overcome scientific and technological barriers, because failing to do so hinders the diffusion of the technology. Market and financial barriers, such as the potential high cost for final consumers, are still very important, but they can only be addressed once the other barriers are overcome.

[3] According to current European Union TRL definitions, a level between 3 and 4 represents a technology that is in transition from an experimental proof of concept to validating components in the laboratory.

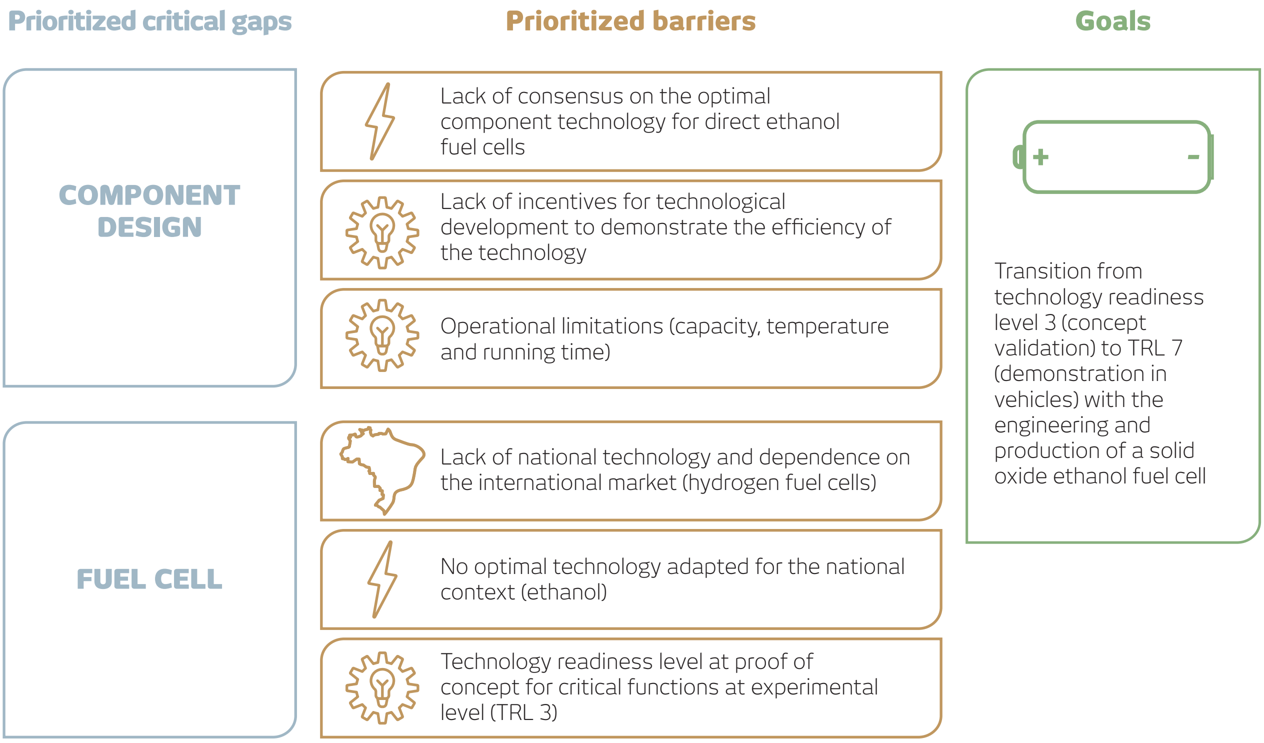


Figure 8 – Critical gaps and barriers and priority goals

Source: the author.

Actions and activities

As mentioned above, the Plan is divided into two phases. The first involves activities aimed at building a prototype of a complete system for various applications, from the manufacturing of the stack components to the preparation of the balance of plant, which includes all the required auxiliary systems for the fuel cell to operate. The second phase consists of larger projects aimed at increasing the scale of production to semi-industrial, culminating in the installation of a pilot prototype and balance of plant in a vehicle for testing and operation in real use conditions.

The TAP actions related to the manufacturing of components and balance of plant were guided, primarily, by a US Navy project to develop SOFC prototypes with ethanol reformers for different applications (ACI TECHNOLOGIES, 2011). Based on this, we propose the expansion and specification of the technology. The study was considered a valid basis, given the modular nature of SOFCs and bearing in mind that the prototyping activities are similar.

Action 1 and related activities

Action 1 involves a number of measures for preparing the TAP activities, with a general project design and the creation of protocols for obtaining raw materials.

The first activity in this action involves preparing an executive project with the goal of defining the team, selecting managers and contracting specialized labor capable of coordinating the execution of the different TAP stages. In addition, a communication plan should be developed and implemented to identify the TAP target group, as well as to disseminate the results of different actions and activities to attract potential partners. The second activity concerns the small-scale synthesis of ceramic materials and suspensions for electrodes and electrolyte. As mostly ceramic raw material is used, it is necessary to ensure quality control of the product purchased for the manufacturing in this activity. The third and last activity aims to ensure the quality of the synthesized product, leading to the development of quality protocols for the acquired ceramic raw materials and the ceramic suspensions.

Table 23 – Action 1 and related activities

ACTION 1 – PROJECT IMPLEMENTATION MANAGEMENT AND COMMUNICATIONS AND SYNTHESIS, DEVELOPMENT AND APPLICATION OF QUALITY CONTROL PROTOCOLS FOR THE CERAMIC RAW MATERIALS FOR THE PRODUCTION OF THE CATHODE, ANODE AND ELECTROLYTE	
Sub-activity 1.1	Elaboration of the executive project and the communication plan; selection and contracting of the teams responsible for implementing the project
Sub-activity 1.2	Small-scale synthesis of ceramic materials and suspensions for electrodes and electrolyte
Sub-activity 1.3	Development and application of quality control protocols for the ceramic raw materials using analytical methods, sample sizing and quality control after production

Source: the author.

Action 2 and related activities

Action 2 involves the production and characterization of the individual SOFCs. The first activity is the selection of the SOFC type (flat or tubular, among others) and the spatial arrangement of the components, as well as the selection of the production processes for cathodes, anodes and electrolytes from the suspensions in Action 1 (using the referenced patents and literature as a basis). The second activity in this action involves bench-scale manufacturing of the SOFC designed in sub-activity 2.1. The final activity of this action is the characterization, using analytical methods, for quality control of the individual cells.

Table 24 – Action 2 and related activities

ACTION 2 – PRODUCTION AND CHARACTERIZATION OF THE INDIVIDUAL SOLID OXIDE FUEL CELLS (SOFCS)	
Sub-activity 2.1	Design of individual SOFCs with selection of their structure and the technology for the electrolyte and electrodes
Sub-activity 2.2	Small-scale production of individual SOFCs in collaboration with a partner company
Sub-activity 2.3	Characterization of individual SOFCs to determine conformity

Source: the author.

Action 3 and related activities

Action 3 consists of the manufacturing and application of test cycles for the interconnecting devices and the base and top plates for the stacks.

The first activity in this action involves the design of the interconnectors and the base and top plates by the permanent project team, with the involvement of one or more highly qualified metalworking companies in order to avoid limitations, such as lack of precision or cutting patterns for this type of application in the market. The second activity in the action consists of the actual small-scale manufacturing of the interconnectors and cutting the metal base and top plates according to the design standards for the stacks. The final activity is the development and application of a test cycle for the manufactured products to determine compliance and optimize the components to reduce costs.

Table 25 – Action 3 and related activities

ACTION 3 – PRODUCTION AND APPLICATION OF TEST CYCLES FOR INTERCONNECTING DEVICES AND BASE AND TOP PLATES	
Sub-activity 3.1	Design of interconnectors and base and top plates
Sub-activity 3.2	Small-scale manufacturing of interconnectors and base and top plates by qualified metalworking company
Sub-activity 3.3	Development and application of a test cycle to determine compliance and optimize components to reduce costs

Source: the author.

Action 4 and related activities

Action 4 consists of the manufacturing and characterization of the coatings and sealants for the stacks.

The first activity aims to develop laboratory-scale processes for the production and application of coatings for stack components and sealants with maximum physical and thermal stability and optimal stack performance. Following this, market research on the raw materials for coatings and sealants should be conducted, with these materials selected according to availability and performance requirement criteria. Finally, there is the characterization, using analytical methods, for quality control of the application of sealants and coatings.

Table 26 – Action 4 and related activities

ACTION 4 – PRODUCTION AND CHARACTERIZATION OF COATINGS AND SEALANTS	
Sub-activity 4.1	Development of laboratory-scale processes for the production and application of coatings and sealants for stack components
Sub-activity 4.2	Research on raw material suppliers for coatings and sealants and selection of materials according to availability and performance requirements
Sub-activity 4.3	Characterization experiments (electrical and thermal performance, density, uniformity and thickness of coatings and sealants)

Source: the author.

Action 5 and related activities

Action 5 consists of the manufacturing and characterization of the system to support the stacks.

The first activity involves the selection of the best materials and structures, based on the operating parameters and design of the individual SOFCs, interconnectors and base and top plates, to manufacture the systems that will house the fuel cell stacks. The second activity involves research on material suppliers and companies specialized in the manufacturing of the systems in order to select the most cost-effective option. The third activity consists of acquiring the materials (after market research) to manufacture the housing systems. The final activity involves the characterization of the systems and components using analytical methods to determine structural conformity to ensure the systems have adequate quality to house the stacks.

Table 27 – Action 5 and related activities

ACTION 5 – PRODUCTION AND CHARACTERIZATION OF THE STACK HOUSING SYSTEM	
Sub-activity 5.1	Selection of materials and structures based on the operating parameters and the design of the individual SOFCs, interconnectors and base and top plates
Sub-activity 5.2	Research on material suppliers and companies specialized in the manufacturing of the systems
Sub-activity 5.3	Acquisition of materials and manufacturing of systems
Sub-activity 5.4	Characterization of systems and components aimed at determining conformity

Source: the author.

Action 6 and related activities

Action 6 focuses on the production of the balance of plant systems, which are the subsystems for conditioning reagents and products, thermal management, conditioning of the electrical power produced and control and monitoring.

The first activity involves the design of the balance of plant system and selection of component technology, structure and materials to meet the requirements of the specified operating conditions. The balance of plant is the integration of the engineering system components to make the system function. We suggest, early in the project, researching and contacting manufacturers of heat exchangers, pump system suppliers, highly qualified metalworking companies, suppliers of control and monitoring systems and companies specialized in power electronics that will be responsible for making or supplying the systems used in the balance of plant.

The second activity involves the selection of systems available on the market, aimed at ensuring the best cost-benefit ratio. Then, the design of special components is carried out in the event that commercial equipment is unavailable, identifying the most suitable materials and production and assembly methods for the application and ensuring the balance of plant is complete. The fourth activity involves the acquisition of the selected systems and the production of the special components, completing the design of the balance of plant. The final activity involves the testing of all systems and components (purchased or manufactured) to ensure they meet the performance, durability and efficiency requirements for optimum operation of the balance of plant.

Table 28 – Action 6 and related activities

ACTION 6 – PRODUCTION AND TESTING OF BALANCE OF PLANT SYSTEMS AND COMPONENTS (REAGENT AND PRODUCT CONDITIONING SUBSYSTEMS, THERMAL MANAGEMENT, CONDITIONING OF THE ELECTRIC POWER PRODUCED, CONTROL AND MONITORING)	
Sub-activity 6.1	Design of the balance of plant system and selection of component technology, structure and materials aimed at meeting the specified operating conditions
Sub-activity 6.2	Selection of commercially available systems, with a focus on cost reductions
Sub-activity 6.3	Design of special components in the event commercial equipment is unavailable, identifying the most suitable materials and production and assembly methods for the application
Sub-activity 6.4	Acquisition of selected commercial systems and production of special components by specialized companies
Sub-activity 6.5	Testing of systems and components (performance, durability and efficiency) to determine compliance

Source: the author.

Action 7 and related activities

Action 7 consists of assembling the stacks, with all the elements from the other actions.

The first activity involves consulting the literature and mapping scalable methods for the stacks to create the laboratory infrastructure for assembling the stacks. The second activity consists of assembling the stacks, using the methods and infrastructure of the previous activity, including the application of sealants and coatings.

Table 29 – Action 7 and related activities

ACTION 7 – STACK ASSEMBLY	
Sub-activity 7.1	Identification of scalable methods and creation of laboratory infrastructure for assembling stacks
Sub-activity 7.2	Assembly of stacks, including the application of sealants and coatings

Source: the author.

Action 8 and related activities

Action 8 consists of the activation (necessary for the cells to work together) and testing the assembled stacks.

The first activity aims to design and construct laboratory equipment aimed at conditioning the stacks, applying sealant, increasing contact between the parts and increasing the temperature of the cells. The second activity involves the development and application of testing routines to check for leaks after conditioning to ensure waterproofing and reduce equipment failure risks. This is followed by the design and construction of laboratory equipment capable of electrically activating the stacks (similar to the first activity). The fourth activity consists of the development and application of electrochemical performance testing routines after activation (similar to the second activity), but with a focus on electrochemical performance.

Table 30 – Action 8 and related activities

ACTION 8 – STACK ACTIVATION AND TESTING	
Sub-activity 8.1	Design and construction of laboratory equipment for conditioning the stacks (sealing, increased contact between the parts and raising stack temperature)
Sub-activity 8.2	Development and application of testing routines to check for leaks after conditioning
Sub-activity 8.3	Design and construction of laboratory equipment for electrochemically activating the stacks
Sub-activity 8.4	Development and application of electrochemical performance testing routines after activation

Source: the author.

Action 9 and related activities

Action 9 involves the assembly and testing of the balance of plant to ensure the integration of all subsystems with the stacks.

The first activity consists of identifying methods and creating the laboratory infrastructure for assembling the balance of plant. The identification of methods should be based on other fuel cells with similar balance of plant characteristics to guarantee a robust process. Following this, the balance of plant is assembled using the manufactured or purchased subsystems to complete the stack. The last activity involves the development and application of performance testing routines for the balance of plant and assembly components to ensure adequate performance. This is extremely important for the future assembly of the laboratory prototype and should take into consideration the tests previously carried out on the balance of plant subsystems in sub-activity 6.5.

Table 31 – Action 9 and related activities

ACTION 9 – ASSEMBLY AND TESTING OF THE BALANCE OF PLANT	
Sub-activity 9.1	Identification of methods and creation of laboratory infrastructure for assembling the balance of plant
Sub-activity 9.2	Assembly of the balance of plant
Sub-activity 9.3	Development and application of performance testing routines for the balance of plant components and complete system

Source: the author.

Action 10 and related activities

This action involves the assembly, characterization and laboratory testing of the complete prototype system (TAP phase 1 objective). This is the stage that culminates in the first prototype with technology readiness level 5 (TRL 5).

The first activity consists of the identification of scalable methods and the creation of the laboratory infrastructure for coupling the stack with the housing system and balance of plant to simulate a complete system. The next activity uses the methods of the previous activity to create the complete system. Finally, performance testing routines are developed and applied to the complete system and the results are compared with other prototypes.

Table 32 – Action 10 and related activities

ACTION 10 – ASSEMBLY, CHARACTERIZATION AND LABORATORY TESTING OF THE COMPLETE PROTOTYPE SYSTEM	
Sub-activity 10.1	Identification of scalable methods and creation of laboratory infrastructure for coupling the stack with the housing system and balance of plant
Sub-activity 10.2	Coupling the stack with the housing system and balance of plant
Sub-activity 10.3	Development and application of performance testing routines for the complete system at technology readiness level 5 (TRL 5)

Source: the author.

Action 11 and related activities

Action 11 involves preparing and filing patents for materials, devices, systems, programs and processes.

The first activity involves the definition of materials, devices, systems, programs and processes subject to patenting, and their development in the project, before any scientific dissemination is carried out. The second activity consists of an extensive bibliographical review and research in patent offices for materials, devices, systems, programs and processes subject to patenting and their development in the project to support the next activity. The last activity concerns the preparing and filing of patents in different patent offices, with a focus on Brazil, the United States and Europe, to protect the innovative intellectual property developed by raising the technology's TRL. It should be noted that the implementation schedule and costs were estimated to be compatible with the preparation and filing of patents, which are two years and BRL 150,000, respectively.

Table 33 – Action 11 and related activities

ACTION 11 – PREPARING AND FILING PATENTS FOR MATERIALS, DEVICES, SYSTEMS, PROGRAMS AND PROCESSES	
Sub-activity 11.1	Definition of materials, devices, systems, programs and processes subject to patenting and their development in the project before any scientific dissemination is carried out
Sub-activity 11.2	Bibliographical review and search in patent offices
Sub-activity 11.3	Preparing and filing of patents in different patent offices, focusing on Brazil, the United States and Europe

Source: the author.

Action 12 and related activities

Action 12 consists of evaluating the viability of the prototype in an activity to prepare and disseminate a study to point out elements for technical and economic evaluation for the application of the prototype in vehicles and/or for stationary generation. This action marks the end of Phase 1 of the Plan.

Table 34 – Action 12 and related activities

ACTION 12 – FEASIBILITY OF USING THE COMPLETE PROTOTYPE-SYSTEM IN DIFFERENT APPLICATIONS (VEHICLES OR STATIONARY GENERATION IN ISOLATION OR ON-GRID)	
Sub-activity 12.1	Elaboration and dissemination of a study on the potential use of the complete prototype system in different applications in vehicles or for stationary generation (isolated or on-grid)
END OF PHASE 1	

Source: the author.

Action 13 and related activities

Action 13 consists of scaling up and adapting the laboratory and production processes of the developed stack components.

The first activity involves the scaling up of the synthesis of materials and ceramic suspensions for electrodes and electrolyte, addressing the adaptation of processes, infrastructure, production and quality control. This is followed by the elaboration of the design and the application of continuous processes of electrolyte and electrode formation and deposition, as well as the creation of adequate infrastructure. Sub-activity 13.3 aims to develop new quality control procedures for individual cells, using bench production processes as a basis. The next activity consists of scaling up the production of interconnectors and base and top plates. Finally, there are the final validations and conformity tests of the coatings and sealants. This activity is similar to Action 4, with the increase in scale and production.

Table 35 – Action 13 and related activities

ACTION 13 – SCALING UP AND ADAPTATION OF LABORATORY AND PRODUCTION PROCESSES FOR STACK COMPONENTS	
Sub-activity 13.1	Scaling up of the synthesis of materials and ceramic suspensions for electrodes and electrolyte and adaptation of processes, creation of infrastructure and production and quality control
Sub-activity 13.2	Design and application of continuous electrolyte and electrode deposition and formation processes and creation of adequate infrastructure
Sub-activity 13.3	Development and application of quality control procedures for individual SOFCs, focusing on thickness, topography and homogeneity of materials and electrochemical performance testing
Sub-activity 13.4	Scaling up of production of interconnectors and base and top plates, adaptation of processes, creation of infrastructure and production and quality control
Sub-activity 13.5	Adaptation of production processes for coatings and sealants for pilot scale use and creation of the necessary infrastructure. Final validations and conformity testing of the coatings and sealants

Source: the author.

Action 14 and related activities

Action 14 involves scaling up production of the stack systems developed in Phase 1.

The first activity consists of researching best industry practices for cutting and assembling electrical and thermal insulation and for manufacturing the mechanical support structure. The next activity addresses the application of techniques to scale up production of the stack housing systems, as well as quality control and development of inspection processes.

Table 36 – Action 14 and related activities

ACTION 14 – SCALE UP OF PRODUCTION OF STACK HOUSING SYSTEMS	
Sub-activity 14.1	Research on best industry practices for cutting and assembling electrical and thermal insulation and for manufacturing the mechanical support structure. Construction of the necessary infrastructure
Sub-activity 14.2	Application of techniques to scale up production of stack housing systems. Quality control and development of inspection processes

Source: the author.

Action 15 and related activities

Action 15 involves assembling the balance of plant on a pilot scale and quality control to ensure optimal functioning.

The first activity involves possible modifications and substitutions of commercial and special components of the balance of plant aimed at increasing efficiency and lowering costs. Additionally, it addresses testing the replaced components. The next activity involves the development of processes and infrastructure for the manufacturing and assembly of systems and components, based on SOFC best practices, whenever possible. Finally, the pilot balance of plant is assembled and post-assembly quality control inspection is carried out with the modifications to the quality control process (Action 6).

Table 37 – Action 15 and related activities

ACTION 15 – ASSEMBLY OF BALANCE OF PLANT ON A PILOT SCALE AND QUALITY CONTROL	
Sub-activity 15.1	Implementation of possible modifications and substitutions of commercial and special components of the balance of plant, aimed at increasing efficiency and lowering costs. Testing of substituted components
Sub-activity 15.2	Development of processes and infrastructure for manufacturing and assembling systems and components
Sub-activity 15.3	Assembly of pilot balance of plant and post-assembly quality control inspection

Source: the author.

Action 16 and related activities

Action 16 involves the assembly of pilot series connected stack and inspection of automated processes, ensuring small-scale production quality.

The first activity involves the identification of scalable assembly methods for stacks, from laboratory to pilot series connected cells, and based on the methods in Action 8. The next activity involves the production of equipment for assembling series connected stacks on a pilot scale based on what currently exists in the industry. The next stage involves the assembly of pilot series connected stacks using automated methods to reduce risks and ensure greater uniformity. Finally, systematics and tools capable of inspecting automated processes are developed and applied, aimed at determining compliance. It should be noted that the activity requires extensive revision, not only in the fuel cell industry, but also in any high-precision industrial assembly process.

Table 38 – Action 16 and related activities

ACTION 16 – ASSEMBLY OF THE PILOT SERIES CONNECTED STACKS AND INSPECTION OF AUTOMATED PROCESSES	
Sub-activity 16.1	Identification of scalable stack assembly methods, from laboratory to pilot series connected stacks
Sub-activity 16.2	Production of equipment in partnership for assembling pilot series connected stacks
Sub-activity 16.3	Assembly of pilot series connected stacks using automated methods
Sub-activity 16.4	Development and application of systems and tools for inspecting automated processes to ensure compliance

Source: the author.

Action 17 and related activities

Action 17 consists of the activation and testing of pilot stacks.

Initially, Action 17 involves the design and construction of pilot equipment to condition the series connected stacks. This activity is similar to Action 8, addressing the necessary modifications for scaling up the prototype. This is followed by developing and applying pilot-level testing routines to check for leaks after conditioning as part of the ongoing evolution of the tests carried out in Action 8 at the small-scale production level. The third activity refers to the design and construction of pilot equipment for electrochemically activating the series connected stacks. Finally, there is the development and application of testing routines for the electrochemical performance of pilot-level stacks after activation, which employ the same methodology as sub-activity 17.2.

Table 39 – Action 17 and related activities

ACTION 17 – ACTIVATION AND TESTING OF PILOT SERIES CONNECTED STACKS	
Sub-activity 17.1	Design and building of pilot equipment for conditioning series connected stacks
Sub-activity 17.2	Development and application of pilot level testing routines to check for leaks after conditioning
Sub-activity 17.3	Design and building of pilot equipment for electrochemically activating the series connected stacks
Sub-activity 17.4	Development and application of testing routines for electrochemical performance of pilot stacks after activation

Source: the author.

Action 18 and related activities

Action 18 consists of the assembly, characterization and testing of the complete pilot series connected stack system, ensuring quality compatible with the new prototype.

The first stage involves the identification of scalable methods and the creation of a pilot infrastructure for coupling the stacks with the housing systems and balance of plant. This step is similar to Action 10, and equally crucial to the success of the Phase 2 pilot prototype, but with a focus on applications in vehicles. Sub-activity 18.2 involves the coupling of the series connected stacks, taking into account the type of vehicle and the likely conditions of use of the complete system in the pilot operation. At this stage, the involvement of automobile companies is crucial to validate the results. The last stage aims to develop tests, taking into account the use profiles of the vehicles using the technology.

Table 40 – Action 18 and related activities

ACTION 18 – ASSEMBLY, CHARACTERIZATION AND TESTING OF THE COMPLETE PILOT SERIES CONNECTED SYSTEM	
Sub-activity 18.1	Identification of scalable methods and creation of pilot infrastructure for coupling stacks with housing system and balance of plant
Sub-activity 18.2	Coupling of series connected stacks with housing system and balance of plant using pilot equipment
Sub-activity 18.3	Development and application of performance testing routines of assembled complete series connected systems using pilot equipment, in order to determine compliance

Source: the author.

Action 19 and related activities

Action 19 consists of the installation and testing of the pilot system in real use conditions in a fuel cell electric vehicle.

The first activity involves the selection and acquisition of the vehicle for the on-board demonstration of the pilot system under real use conditions. This is followed by design of the installation and operating mode for carrying out the on-board demonstration of the pilot system under real use conditions. Finally, the system is tested in a vehicle under real use conditions to attain TRL 7. A crucial part of this step is the comparison with other pilot systems in vehicles, including comparisons with different fuel cell technologies.

Table 41 – Action 19 and related activities

ACTION 19 – INSTALLATION AND TESTING OF THE PILOT SYSTEM IN A FUEL CELL ELECTRIC VEHICLE UNDER REAL USE CONDITIONS	
Sub-activity 19.1	Selection and acquisition of the vehicle to carry out the on-board demonstration of the pilot system under real use conditions
Sub-activity 19.2	Design of the installation and operating mode for the on-board demonstration of the pilot system under real use conditions
Sub-activity 19.3	Testing of the pilot system in a vehicle under real use conditions to attain technology readiness level 7 (TRL 7)

Source: the author.

Action 20 and related activities

Action 20 consists of preparing and filing patents for materials, devices, systems, programs and processes. This activity is similar to Action 11, though it implies a significantly higher workload and, consequently, higher costs.

The first activity involves determining the materials, devices, systems, programs and processes subject to patenting, and their development in the project, before any scientific dissemination is carried out. Then, a bibliographical review and research in patent offices should be carried out on materials, devices, systems, programs and processes subject to patenting and their development in the project. Finally, there is the preparation and filing of patents in different patent offices, with a focus on Brazil, the United States and Europe. The time frame for the implementation of this activity is compatible with its complexity (24 months) and the cost of filing patents (BRL 450,000).

Table 42 – Action 20 and related activities

ACTION 20 – PREPARATION AND FILING PATENTS FOR MATERIALS, DEVICES, SYSTEMS, PROGRAMS AND PROCESSES	
Sub-activity 20.1	Determination of materials, devices, systems, programs and processes subject to patenting, and their development in the project, before any scientific dissemination is carried out
Sub-activity 20.2	Bibliographical review and research in patent offices on materials, devices, systems, programs and processes subject to patenting and their development in the project
Sub-activity 20.3	Preparing and filing of patents in different patent offices, focusing on Brazil, the United States and Europe

Source: the author.

Action 21 and related activities

The last TAP action is the dissemination of project results and taking the next steps in the development of the technology.

The first activity involves the preparation of the final project reports and actions to communicate the results in policy briefs and fact sheets, in addition to an event to disseminate the project results. The final activity consists of preparing a publication and project proposal for the diffusion of the technology in the country, with a draft project to develop the technology to TRL 8 and TRL 9, preparing the groundwork for the technology to move beyond the scope of the TAP. At this stage, monitoring the staff responsible for implementing the TAP communication plan is essential.

Table 43 – Action 21 and related activities

ACTION 21 – DISSEMINATION OF THE FINAL PROJECT RESULTS AND NEXT STEPS FOR THE DEVELOPMENT OF THE TECHNOLOGY	
Sub-activity 21.1	Preparation of final project reports and actions to communicate the results
Sub-activity 21.2	Publication and project proposal for the diffusion of the technology in the country
END OF PHASE 2	

Source: the author.

3.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

To implement the action plan, different stakeholders from academia, industry and public and private sectors are required. The heterogeneity of stakeholders involved is fundamental to the robustness of the decisions made during the execution of the activities, ensuring the quality of the products delivered at the end of each stage.

Considering the Plan involves state-of-the-art technology that can result in technology products that do not exist in national and international markets, and which are strategic for the transport and ethanol sector in Brazil, we believe that the MCTI should be involved in the coordination. The MCTI could also propose implementation arrangements for the Plan that include a Technical Advisory Committee. This Committee could involve the MME, MDR and ANP.

To execute the TAP activities, a technical team should be created for each action. The technical teams should be composed of (or at least involve) members of one or more leading research institutes and centers, who should act under MCTI coordination.

Some activities involve building infrastructure. It is understood that creating a startup is necessary to industrialize and improve the processes from Phase 1 onward. It would act as a satellite company for the technical team.

We can highlight other stakeholders with recognized expertise in the technology, or whose missions could contribute to the TAP, including: i) potential financing agencies for TAP activities (ME, Finep, BNDES, CNPq, Embrapii); ii) companies specialized in SOFCs (Adelan Ltd., Aisin Seiki Co., Bloom Energy, Ceres Power Plc., Convion Ltd., Elcogen AS, Energiah Ltda. and Hexis AG, among others); iii) different service providers; and iv) quality certifying agencies (Inmetro).

Table 44 – Main stakeholders to involve in implementing the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
MCTI	The MCTI is involved in the following areas: national telecommunications policies, scientific and technological research, information technology and automation, among others. It could act in coordinating the implementation of the TAP.
MME	The MME establishes the guidelines for the elaboration of public policies for the energy sector and coordinates the elaboration and implementation of Brazilian energy planning instruments, such as the Ten Year Energy Expansion Plan, the National Energy Plan and the National Energy Balance, in addition to coordinating energy information systems. The MME could be responsible for the TAP Technical Advisory Committee.
MDR	The Ministry of Regional Development (MDR) was created in January of 2019 with the task of integrating, in a single portfolio, the various public policies for urban infrastructure and the promotion of regional and economic development. Due to the alignment between the TAP actions and the MDR's mission, this Ministry could be part of the Technical Advisory Committee.
ANP	The ANP is the federal agency responsible for regulating the oil and natural gas and biofuels industries in Brazil. It could be part of the TAP Technical Advisory Committee.
Leading research institutes and centers in the area	They could play a role in designing the cells and stacks, the execution of activities, and in processes and quality control. They should be the main technical partners and responsible for prototyping.
ME	The ME is responsible for the formulation and execution of national economic policies and the financial administration of the State. It could act in the mobilization of stakeholders to finance TAP actions.

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STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Finep	Finep promotes science, technology and innovation in companies, universities, technological institutes and other public and private institutions. It operates throughout the innovation chain, focusing on strategic, structural and impact actions for the sustainable development of Brazil. It could act as a financing agent for TAP activities.
BNDES	BNDES is the Federal Government instrument for long-term financing and investments in all segments of the Brazilian economy. It could act as a financing agency for TAP activities.
CNPq	CNPq promotes and fosters Brazil's scientific and technological development and contributes to the formulation of national science and technology policies. It could play a role in supporting TAP activities.
Embrapii	Embrapii supports technological research institutions to carry out technology research development projects for innovation in cooperation with companies in the industrial sector. It could act in activities to promote the TAP.
Specialized SOFC technology Companies	International companies specializing in solid oxide fuel cell technology could provide services for carrying out activities, monitoring or consulting for the project.
Various companies	Different companies could provide the following services (in several actions): i) highly qualified metalworking; ii) supply or manufacturing of heat exchangers; iii) supply or manufacturing of pumps and/or pumping systems; iv) supply of coatings and/or sealants; v) high quality metal welding; vi) supply of control and monitoring systems; vii) supply of electronic power systems; and viii) preparation and filing of patents.
Inmetro	The National Institute of Metrology, Standardization and Industrial Quality (Inmetro) is an independent Federal authority that provides infrastructure that facilitates solutions to promote trust, quality and the competitiveness of the products and services of Brazilian organizations. It could act as an auxiliary stakeholder, especially in quality control processes and consulting on actions to develop adequate quality management techniques. It could play a role in Actions 1, 4 and 6.
Cetem	The Mineral Technology Center (Cetem) is a research institution that works on projects to serve companies in the mining, metallurgy, petroleum, chemical and materials sectors. It could act as an auxiliary stakeholder, either as a consultant or in the execution of activities for the technological characterization of high performance materials. It could play a role in Actions 1 and 4.
Inpi	The National Institute of Intellectual Property (Inpi) is a federal agency that executes norms for the regulation of intellectual property in Brazil. As an auxiliary stakeholder, it would undertake the patent filing process in Brazil. It could play a role in Actions 11 and 20.
Automotive sector companies	They could be involved as a target of TAP Actions 12 and 21.

Source: the author.

Schedule of actions and activities

The time frame for implementing the TAP is six years, a time considered adequate for the technical and financial preparation and implementation of the TAP activities for developing ethanol fuel cell electric vehicles.

The Plan is divided into two phases, with the first ending at the end of the third year, and the second at the end of the sixth year. By necessity, they are planned in a sequential manner, with Phase 2 depending on the successful conclusion of the previous phase.

Actions 1 to 6 can be performed simultaneously as they produce complementary parts of a whole. In Actions 7 to 10, the parts of the prototype are connected and tested, so that each action depends, at least in part, on what precedes it. Actions 11 and 12 are not manufacturing and engineering actions, like the previous ones, meaning that Action 11 progresses over Phase 1, and Action 12 depends on the results of the other actions to prepare the report on the working prototype.

The Phase 2 Actions of the project, with the exception of 13 and 14, are interdependent with respect to the previous ones. Actions 20 and 21 are similar to Actions 11 and 12, with the first occurring over Phase 2 and the second depending on the results of the others.

Table 45 – TAP implementation schedule

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
1.1	■																	
1.2	■	■																
1.3	■	■																
2.1	■	■																
2.2		■	■															
2.3			■	■														
3.1	■	■																
3.2		■	■															
3.3			■	■														
4.1	■	■																
4.2		■	■															
4.3			■	■														
5.1		■	■															
5.2		■	■															
5.3			■	■														
5.4				■	■													

continues

continuation

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
6.1	■	■																
6.2	■	■	■															
6.3		■	■															
6.4		■	■	■														
6.5			■	■	■													
7.1		■	■															
7.2			■	■	■													
8.1		■	■															
8.2			■	■	■													
8.3		■	■															
8.4			■	■	■													
9.1			■	■														
9.2				■	■													
9.3					■	■												
10.1			■	■														
10.2				■	■													
10.3					■	■												
11.1	■	■	■	■	■													
11.2		■	■	■	■													
11.3			■	■	■	■												
12.1				■	■	■												
13.1							■											
13.2							■	■										
13.3								■	■									
13.4							■	■	■									
13.5							■	■	■									
14.1							■	■										
14.2								■	■									

continues

continuation

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
15.1							■	■	■									
15.2								■	■									
15.3									■	■								
16.1							■	■										
16.2								■	■									
16.3									■	■								
16.4									■	■	■							
17.1								■	■									
17.2									■	■								
17.3								■	■									
17.4									■	■	■							
18.1									■	■								
18.2										■	■							
18.3										■	■	■						
19.1							■	■	■									
19.2								■	■	■								
19.3									■	■	■	■						
20.1							■	■	■	■	■							
20.2								■	■	■	■							
20.3									■	■	■	■						
21.1								■		■		■						
21.2												■						

Source: the author.

3.5. TAP implementation costs and financing options

The total cost of the TAP was estimated at approximately BRL 25.5 million. Both phases have similar total costs, with Phase 2 slightly higher. The Phase 2 costs are not much higher than Phase 1 due to the fact that, when increasing the scale, it can take advantage of the processes, methods, testing routines and infrastructure from Phase 1. Some actions have lower costs than others, but none are significantly higher in relation to the total cost, largely due to the large number of actions.

The cost estimates were validated and compared to similar projects, like the ones presented in ACI Technologies (2011). Given the restrictions, it is understood that the American project, by nature, would have higher costs, considering the greater range of applications.

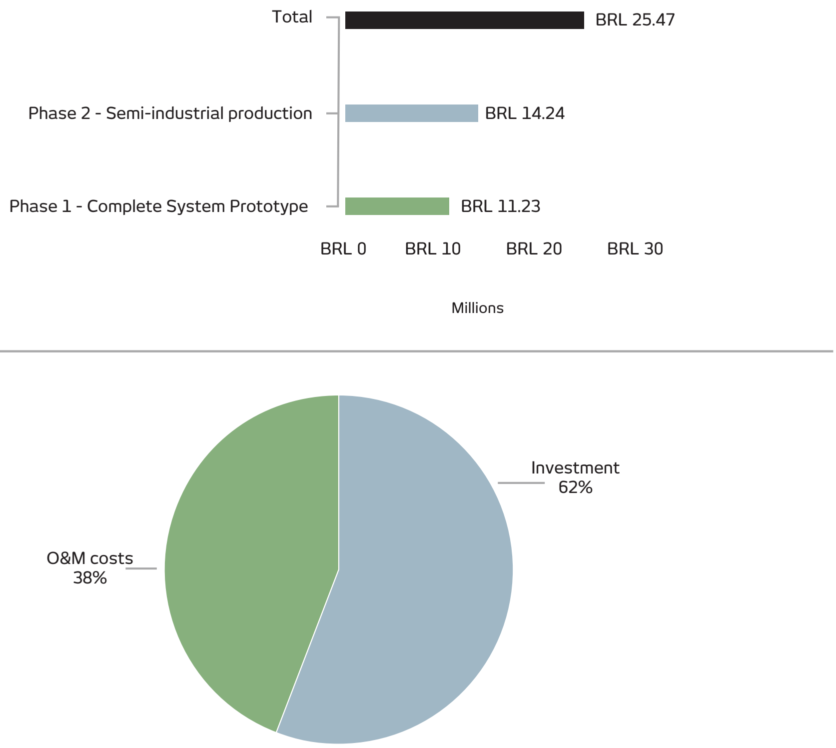


Figure 9 – Total costs per phase, in millions of BRL, for the TAP for ethanol fuel cell electric vehicles

Source: the author.

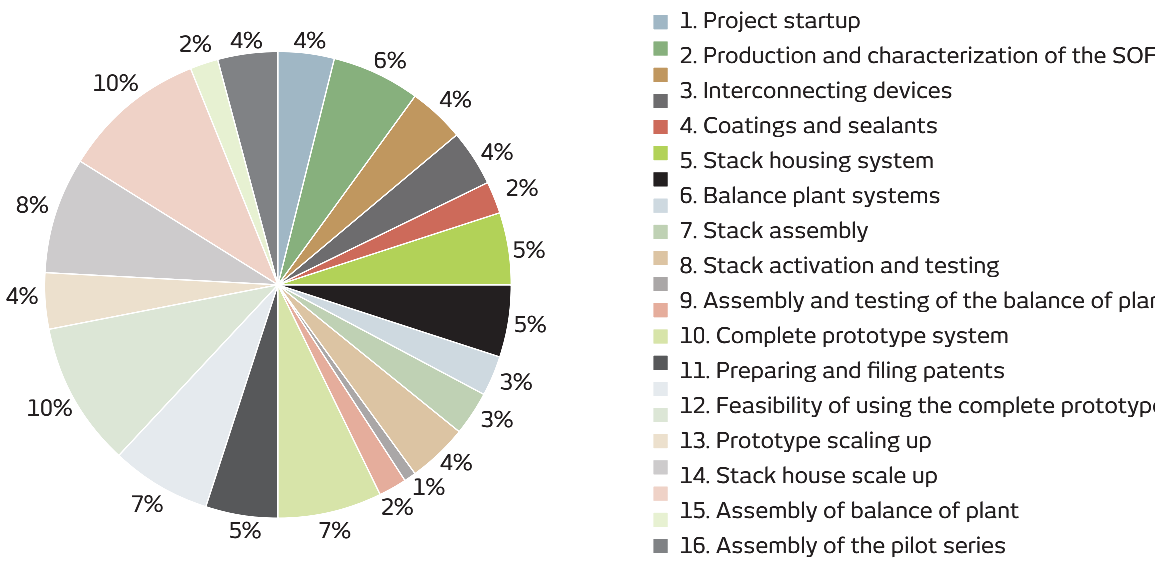


Figure 10 – Costs per action, as a percentage, for the TAP for ethanol fuel cell electric vehicles

Source: the author.

With regard to potential sources of financing for the activities, and with a focus on research and development to reach the stages TRL 5 (Phase 1) and TRL 7 (Phase 2), we determined the typical means of financing would be non-repayable loans and technical assistance. Financing is accessible for state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and in the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b).

3.6. Risk and contingency plan

We analyzed the potential risks involved to implement each group of TAP activities. The following risk categories were considered: political, institutional, organizational, technical and cost risks. They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs). Finally, contingency actions were proposed to mitigate these risks.

The highest risks are associated with sub-activities 5.3 and 6.2, which involve the purchase of high tech and specific equipment, materials and systems that may be difficult to source; and sub-activities 13.1, 13.2, 13.5 and 19.2, which involve the scaling up of processes and/or realization of new semi-industrial projects, often using advanced and pioneering technology.

Sub-activity 5.3 runs the risk of execution accidents, lack of maintenance and equipment breakdown. It is contingent on satisfactory quality control and a partnership with a company capable of assisting or supervising activities.

Sub-activity 6.2 has a high risk of unavailability of components and systems in the domestic and international market, which is contingent on the elaboration of specific designs or adaptation of existing components.

The risks in sub-activity 13.1 are associated with the possible non-scalable nature of processes, inadequate infrastructure, execution accidents due to lack of maintenance and/or equipment breakdown. The contingency actions include an extensive bibliographical review and comparative testing of alternative processes; satellite projects for infrastructure adaptation; identification of a partner company to perform and/or consult on activities; and reserving contingency resources for unforeseen expenses. In sub-activity 13.2, generic design errors may occur, in addition to inadequate infrastructure and execution accidents. The contingency actions are the same as those described above. In sub-activity 13.5, in addition to the same risks and contingencies as sub-activity 13.2, we can add possible compliance false positives, which are contingent on the definition of optimal test parameters.

Sub-activity 19.2 has a high risk due to potential lack of coordination, methodological errors, the environment differing from real use conditions and a lack of qualified labor. Partnerships with automotive industry companies and companies specializing in SOFC technology can reduce these risks, especially combined with a centralized management strategy and contracting sufficient labor.

Table 46 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1. Elaboration of the executive project and communication plan, selection and contracting of the teams responsible for implementing the project	Organizational risk, institutional risk and technical risk	Lack of qualified labor to supervise and contract the teams to carry out the activities. Lack of institutional support. Errors in the elaboration of the executive project. Difficulty in identifying the project's target group.	Low	Contract a supervisor with extensive expertise in the development of fuel cell technologies. Use robust methodology for preparing executive projects. Validation of the executive project by research and development and innovation institutes. Prepare and implement a communication plan.
1.2. Small-scale synthesis of ceramic materials and suspensions for electrodes and electrolyte	Technical risk	Lack of qualified labor for bench-level activities.		Contract labor in leading research centers with extensive expertise in the area.
1.3. Development and application of quality control protocols for the ceramic raw material, using analytical methods, sample sizing and quality control after production	Organizational risk	Lack of prioritization for cost reductions and lack of manager interest.		Involve stakeholders and convince them of the importance of the action.
2.1. Design of individual SOFCs with selection of the structure and technology for the electrolyte and electrodes	Technical risk and organizational risk	Lack of coordination in the design of structures and methodological errors. Lack of qualified labor.	Low	Validation by an external specialist or via workshop with specialists. Ensure the technical coordination of the activity in the budgeted team and contract labor in leading research centers. Inspections and testing in partnership with leading research centers.
2.2. Small-scale production of individual SOFCs in collaboration with a partner company		Lack of coordination between laboratory and partner company. Human error in the execution of process steps.	Medium	Research the market to select the most suitable company for the technology in question. Quality control (by the laboratory or by the company).
2.3. Characterization of individual SOFC for determining conformity	Technical risk	Compliance false positives.	Low	Development of feedback loop to identify optimal characterization parameters.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
3.1. Design of interconnectors and base and top plates	Technical risk and organizational risk	Lack of coordination in the design and methodological errors. Lack of qualified labor.	Low	Validation by an external specialist or via workshop with specialists. Ensure the technical coordination of the activity in the budgeted team and contract labor in leading research centers. Inspections and testing in partnership with leading research centers.
3.2. Small-scale manufacturing of interconnectors and base and top plates by metalworking company		Lack of coordination between laboratory and partner company. Human error in the execution of process steps.	Medium	Research the market to select the most suitable company for the technology in question. Quality control (by the laboratory or by the company).
3.3. Development and application of testing cycle to determine compliance and optimize components to reduce costs	Technical risk	Compliance false positives. Human error in optimization.	Low	Develop feedback loop to optimize tests.
4.1. Development of laboratory-scale processes for the production and application of coatings and sealants for stacks and components	Technical risk and organizational risk	Lack of coordination in the project and methodological errors. Lack of qualified labor.	Medium	Validation by an external specialist or via workshop with specialists. Ensure the technical coordination of the activity in the budgeted team and contract labor in leading research centers.
4.2. Research on suppliers of raw materials for coatings and sealants and selection of materials according to availability and requirements	Technical risk	Lack of qualified suppliers.	Low	Import suitable materials.
4.3. Characterization experiments (electrical and thermal performance, density, uniformity and thickness of coatings and sealants)		Characterization false positives.	Medium	Develop feedback loop to identify optimal characterization parameters.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
5.1. Choice of materials and structures based on the operating parameters and design of the individual SOFC and interconnectors and base and top plates	Technical risk and organizational risk	Lack of coordination in the design and methodological errors in the choice of materials. Lack of qualified labor.	Low	Validation by an external specialist or via workshop with specialists. Ensure the technical coordination of the activity in the budgeted team and contract labor in leading research centers.
5.2. Research on material suppliers and specialized manufacturing companies	Technical risk	Lack of qualified suppliers.		Import suitable materials.
5.3. Acquisition of materials and manufacturing of systems	Organizational risk and technical risk	Execution accidents, lack of maintenance, equipment breakdown. Human error in the execution of process steps.	High	Identify partner company capable of assisting or supervising activities. Quality control.
5.4. Characterization of systems and components to determine conformity	Technical risk	Compliance false positives.	Low	Develop feedback loop to identify optimal characterization parameters.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
6.1. Design of the balance of plant system and selection of technology, structure and materials for the components, with a focus on meeting the specified operating conditions	Technical risk and organizational risk	Lack of coordination in the design and methodological errors. Lack of qualified labor.	Low	Validation by an external specialist or via workshop with specialists. Ensure the technical coordination of the activity in the budgeted team and contract labor in leading research centers.
6.2. Selection of commercially available systems, with a focus on cost reductions	Technical risk	Unavailability of components in the domestic and international market	High	Develop custom designs of special components or modify existing equipment (see sub-activities 6.3 and 6.4).
6.3. Design of special components in the event commercial equipment is unavailable, identifying the most suitable materials and production and assembly methods for the application	Technical risk and organizational risk	Lack of coordination in the design and methodological errors. Lack of qualified labor.	Low	Validation by an external specialist or via workshop with specialists. Ensure the technical coordination of the activity in the budgeted team and contract labor in leading research centers.
6.4. Acquisition of selected commercial systems and production of special components by specialized companies		Lack of coordination between laboratory and partner company. Human error in the execution of process steps.	Medium	Research the market to select the most suitable company for the technology in question. Quality control (by the laboratory or by the company).
6.5. Testing of systems and components (performance, durability and efficiency) to determine compliance	Technical risk	Compliance false positives.	Low	Develop feedback loop to identify optimal characterization and testing parameters.
7.1. Identification of scalable methods and creation of laboratory infrastructure for assembling stacks	Technical risk and organizational risk	Methodological errors. Non-scalability of the methods. Lack of qualified labor.	Low	Validation by an external specialist or via workshop with specialists. Contract labor in leading research centers.
7.2. Assembly of stacks, including application of sealants and coatings	Organizational risk and technical risk	Execution accidents, lack of maintenance, equipment breakdown. Human error in the execution of process steps.	Medium	Identify partner company capable of assisting or supervising activities. Quality control. Reserve contingency resources.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
8.1. Design and construction of laboratory equipment for conditioning the stacks (sealing, increased contact between the parts and raising the temperature of the cells)	Technical risk and organizational risk	Execution accidents, lack of maintenance, equipment breakdown. Lack of coordination in the design and methodological errors. Lack of qualified labor.	Medium	Identify partner company capable of carrying out activities. Validation by an external specialist or via workshop with specialists. Ensure the technical coordination of the activity in the budgeted team and contract labor in leading research centers. Reserve contingency resources.
8.2. Development and application of testing routines to check for leaks after conditioning	Technical risk	Human error in quality control.	Low	Develop feedback loop to identify the main problems.
8.3. Design and construction of laboratory equipment for electrochemically activating the stacks	Organizational risk and technical risk	Execution accidents, lack of maintenance, equipment breakdown. Design errors.	Medium	Identify partner company capable of carrying out activities. Carry out an extensive bibliographical review. Conduct comparative tests. Reserve contingency resources.
8.4. Development and application of electrochemical performance testing routines after activation	Technical risk	Human error in quality control.	Low	Develop feedback loop to identify the main problems.
9.1. Identification of methods and creation of laboratory infrastructure for assembling the balance of plant	Technical risk and organizational risk	Methodological errors, non-scalability of methods. Inadequate infrastructure. Lack of qualified labor.	Low	Validation by an external specialist or via workshop with specialists. Contract labor in leading research centers. Develop satellite projects to adapt and expand the laboratory infrastructure.
9.2. Assembly of the balance of plant	Technical risk	Human error in the execution of process steps.	Medium	Inspections and testing routines (sub-activity 9.3).
9.3. Development and application of performance testing routines for the balance of plant components and complete system		Human error in quality control.	Low	Develop feedback loop to identify the main problems.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
10.1. Identification of scalable methods and creation of laboratory infrastructure for coupling the stack with the housing system and balance of plant	Technical risk and organizational risk	Methodological errors, non-scalability of methods. Lack of qualified labor. Inadequate infrastructure.	Low	Validation by an external specialist or via workshop with specialists. Contract labor in leading research centers. Develop satellite projects to adapt and expand the laboratory infrastructure.
10.2. Coupling of stack with the housing system and balance of plant	Technical risk	Human error in the execution of process steps.	Medium	Quality control.
10.3. Development and application of performance testing routines for the complete system at technology readiness level 5 (TRL 5)		Human error in quality control.	Low	Develop feedback loop to identify the main problems.
11.1. Determination of materials, devices, systems, programs and processes subject to patenting, and their development in the project, before any scientific dissemination is carried out	Technical risk	Human error in preparing the documentation, lack of qualified labor.	Low	Constant review by different professionals (peer-review). Contract labor in leading research centers.
11.2. Bibliographical review and research in patent offices on materials, devices, systems, programs and processes subject to patenting, and their development in the project		Bibliographical review too narrow. Ignorance of new patents.		Partnership with patent office able to assist or supervise.
11.3. Preparation and filing of patents in different patent offices, focusing on Brazil, the United States and Europe	Organizational risk	Delays due to the bureaucratic nature of the process.	Medium	File processes early to comply with deadlines.
12.1. Elaboration and dissemination of a study on the potential of using the complete prototype-system in different applications in vehicles or stationary generation (isolated or on-grid)	Technical risk	Human error in preparing the study, lack of qualified labor.	Low	Constant review by different professionals (peer-review). Contract labor in leading research centers.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
13.1. Scale up of the synthesis of materials and ceramic suspensions for electrodes and electrolyte, adaptation of processes, creation of infrastructure and production and quality control	Technical risk and organizational risk	Difficulty in scaling up due to the non-scalable nature of some processes. Inadequate infrastructure. Execution accidents, lack of maintenance, equipment breakdown.	High	Extensive bibliographical review. Conduct comparative tests for alternative processes. Satellite projects to adapt and expand the infrastructure of the laboratory and/or partner company. Identify partner company capable of carrying out activities. Reserve contingency resources.
13.2. Design and application of continuous small-scale electrolyte and electrode deposition and formation processes and creation of adequate infrastructure	Technical risk and organizational risk	Design errors. Inadequate infrastructure. Execution accidents, lack of maintenance, equipment breakdown.	High	Extensive bibliographical review. Conduct comparative tests. Satellite projects to adapt and expand the infrastructure of the laboratory and/or partner company. Identify partner company capable of carrying out activities. Reserve contingency resources.
13.3. Development and implementation of quality control procedures for individual SOFCs, focusing on thickness, topography and homogeneity of materials, and electrochemical performance testing	Technical risk	Human error in quality control.	Low	Develop feedback loop to identify the main problems.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
13.4. Scale up of production of interconnectors and base and top plates, adaptation of processes, creation of infrastructure and production and quality control	Technical risk and organizational risk	Difficulty in scaling up due to the non-scalable nature of some processes. Inadequate infrastructure. Execution accidents, lack of maintenance, equipment breakdown.	Medium	Extensive bibliographical review. Conduct comparative tests for alternative processes. Satellite projects to adapt and expand the infrastructure of the laboratory and/or partner company. Identify partner company capable of carrying out activities. Reserve contingency resources
13.5. Adaptation of coating and sealant production processes for pilot scale and creation of the necessary infrastructure. Final validations and conformity testing of the coatings and sealants produced		Difficulty in scaling up due to the non-scalable nature of some processes. Inadequate infrastructure. Execution accidents, lack of maintenance, equipment breakdown. Compliance false positives.	High	Extensive bibliographical review. Conduct comparative tests for alternative processes. Satellite projects to adapt and expand the infrastructure of the laboratory and/or partner company. Identify partner company capable of carrying out activities. Develop feedback loop to identify optimal characterization and testing parameters. Reserve contingency resources.
14.1. Research on best industry practices for cutting and assembling electrical and thermal insulation and for manufacturing the mechanical support structure. Building of the necessary infrastructure	Technical risk and organizational risk	Industry resistance to share expertise. Difficulty obtaining data. Inadequate infrastructure.	Medium	Identify partner company capable of carrying out activities. Satellite projects to adapt and expand the infrastructure of the laboratory and/or partner company. Draw up TCA.
14.2. Application of techniques to scale up production of stack housing systems. Quality control and development of inspection processes		Execution accidents, lack of maintenance, equipment breakdown. Human error in quality control.		Identify partner company capable of carrying out activities. Develop feedback loop to identify the main problems. Reserve contingency resources.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
15.1. Possible modifications and substitutions of commercial and special components of the balance of plant to increase efficiency and lower costs. Testing of substituted components	Technical risk	Human error in adjusting the balance of plant for subsequent industrial production	Medium	Extensive bibliographical review. Consult best practices with partner companies. Reserve contingency resources.
15.2. Development of small-scale processes and infrastructure for manufacturing and assembling systems and components	Organizational risk and technical risk	Execution accidents, lack of maintenance, equipment breakdown. Human error in the execution of process steps.		Identify partner company capable of carrying out activities. Quality control. Reserve contingency resources.
15.3. Assembly of pilot balance of plant and quality control with post-assembly inspection		Execution accidents, lack of maintenance, equipment breakdown. Human error in quality control.		Identify partner company capable of carrying out activities. Develop a feedback loop to identify the optimal inspection parameters. Reserve contingency resources.
16.1. Identification of scalable stack assembly methods from laboratory to pilot series connected cells	Technical risk and organizational risk	Methodological errors. Non-scalability of the methods. Lack of qualified labor.	Low	Validation by an external specialist or via workshop with specialists. Contract labor in leading research centers.
16.2. Building of equipment, in partnership, for assembling series connected stacks on a pilot scale	Organizational risk	Execution accidents, lack of maintenance, equipment breakdown.	Medium	Inspections and testing in partnership with the executing company. Reserve contingency resources.
16.3. Assembly of series connected stacks using automated methods		Execution accidents, lack of maintenance, equipment breakdown.		Inspections and testing in partnership with the executing company. Reserve contingency resources.
16.4. Development and application of systems and tools for inspecting automated processes to determine compliance	Technical risk	Human error in quality control.	Low	Determine optimal inspection parameters.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
17.1. Design and construction of pilot equipment for conditioning series connected stacks	Technical risk and organizational risk	Lack of coordination in the design and methodological errors. Execution accidents, lack of maintenance, equipment breakdown. Lack of qualified labor.	Medium	Validation by an external specialist or via workshop with specialists. Ensure the technical coordination of the activity in the budgeted team and contract labor in leading research centers. Inspections and testing in partnership with the executing company. Reserve contingency resources.
17.2. Development and application of pilot level testing routines to check for leaks after conditioning	Technical risk	Human error in quality control.	Low	Develop feedback loop to identify the main problems.
17.3. Design and construction of pilot equipment for electrochemically activating the series connected stacks	Organizational risk	Execution accidents, lack of maintenance, equipment breakdown.	Medium	Inspections and testing in partnership with the executing company. Reserve contingency resources.
17.4. Development and application of testing routines for the electrochemical performance of pilot stacks after activation.	Technical risk	Human error in quality control.	Low	Develop feedback loop to identify the main problems.
18.1. Identification of scalable methods and creation of pilot infrastructure for coupling stacks with housing systems and balance of plant	Technical risk and organizational risk	Methodological errors, non-scalability of the methods. Lack of qualified labor.	Low	Validation by an external specialist or via workshop with specialists. Contract labor in leading research centers.
18.2. Coupling of series connected stacks with housing systems and balance of plant using pilot equipment	Technical risk	Execution accidents, lack of maintenance, equipment breakdown.	Medium	Inspections and testing in partnership with the executing company. Reserve contingency resources.
18.3. Development and application of performance testing routines for assembled complete series connected stack systems using pilot equipment to determine compliance		Compliance false positives.	Low	Develop feedback loop to identify optimal characterization and testing parameters.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
19.1. Selection and acquisition of the vehicle to carry out the on-board demonstration of the pilot system under real use conditions	Technical risk	Error in selecting the most promising vehicle for the application.	Low	Carry out extensive bibliographical review jointly with automotive sector companies. Elaborate TCA with automotive company.
19.2. Design of the installation and operating mode to carry out the on-board demonstration of the pilot series connected stack system under real use conditions	Technical risk and organizational risk	Lack of coordination in the design and methodological errors. Difficulties in creating an on-board test environment that makes the prototype viable. Lack of qualified labor.	High	Implement the test in conjunction with the partner vehicle company. Consult best practices with companies specialized in SOFC technology. Validation by an external specialist or via workshop with specialists. Ensure the technical coordination of the activity in the budgeted team and contract labor in leading research centers.
19.3. Testing of the pilot series connected stack system in a vehicle under real use conditions to attain technology readiness level 7 (TRL 7)	Organizational risk and technical risk	Execution accidents, lack of maintenance, equipment breakdown. Inefficient experimental data collection.	Medium	Constant maintenance during the vehicle testing phase in partnership with the automotive company. Develop feedback loop to identify the main problems. Reserve contingency resources.

continues

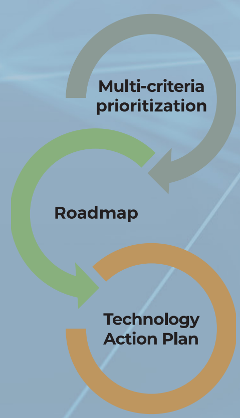
continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
20.1. Determination of materials, devices, systems, programs and processes subject to patenting, and their development in the project, before any scientific dissemination is carried out	Technical risk	Human error in preparing the documentation, lack of qualified labor.	Low	Constant review by different professionals (peer-review). Contract labor in leading research centers
20.2. Bibliographical review and research in patent offices on materials, devices, systems, programs and processes subject to patenting and their development in the project		Bibliographical review too narrow. Ignorance of new patents.		Partnership with patent office able to assist or supervise.
20.3. Preparing and filing of patents in different patent offices, focusing on Brazil, the United States and Europe	Organizational risk	Delays due to the bureaucratic nature of the process.	Medium	File processes early to comply with deadlines.
21.1. Preparation of final project reports	Technical risk	Human error in preparing reports.	Low	Constant review by different professionals (peer-review).
21.2. Launch event and dissemination of project results	Organizational risk and institutional risk	Lack of interest in the study. Delays in the implementation of activities.	Low	Use digital media to mobilize stakeholders interested in learning about the project results. Hold a launch event for the project results report. Ensure compliance with activity deadlines and stipulate penalties in the contract.

Source: the author.

4.

Technology Action Plan **for the use of Agricultural and Agro-industrial Waste**



4. TECHNOLOGY ACTION PLAN FOR THE USE OF AGRICULTURAL AND AGRO-INDUSTRIAL WASTE

4.1. Definition of technology

Agricultural waste has great potential for generating electricity and fuels using renewable sources in Brazil. Furthermore, it offers several benefits, such as reducing GHG emissions, mitigating pollution and fostering local development.

Recent studies indicate a biogas production potential of 23 to 40 million m^3 per day, considering the use of waste in the agriculture and livestock, industrial and urban waste sectors (OLIVEIRA; NEGRO, 2019; EPE, 2016). Currently, the share of biogas in the Brazilian energy matrix is less than 1% (EPE, 2019). However, the installed capacity for generating electricity from biogas has grown significantly in recent years, reaching a total of 153 MW in 2018, 117% higher than in 2013 (FERNANDES; MARIANI, 2019).

This TAP is aligned with the incentive programs for renewable energy sources in Brazil, such as RenovaBio, instituted by Law No. 13.576/2017 (BRASIL, 2017). Understanding the contributions of biofuels, including biomethane generated from biogas, for energy security, market predictability and emissions mitigation, the program addresses three strategic areas: decarbonization targets, production certification and decarbonization credits (BRASIL, 2018).

The goals of the RenovaBio program are to assist Brazil to meet its commitments under the Paris Agreement, promote the expansion of biofuels in the energy matrix (with an emphasis on supply) and to ensure predictability in the market, inducing gains in energy efficiency and reductions in greenhouse gas emissions in the production, commercialization and use of biofuels. In addition, there are also initiatives at the state level to encourage the expansion of biogas and biomethane in the country (SEBRAE, 2020).

In this context, co-digestion projects can contribute even more to increasing the share of renewable energy in Brazil's energy matrix. The technology allows for the use of different types of substrates (waste), thus ensuring the continuous operation of plants and making investments in the sector feasible. This is because the use of different substrates addresses the problem of seasonal waste from agricultural crops, allowing them to complement each other in the biogas plant over the year, in addition to providing a greater volume of waste for energy generation. In this context, integrated crop–livestock–forestry systems (ICLFS) and/or crop rotation systems, for example, are potential niches for the implementation of co-digestion in the country, since these systems can provide potential substrates for anaerobic digestion, as well as ensure more efficient land use.

Table 47 shows the results of a preliminary georeferenced analysis of biogas production potential from co-digestion using animal manure, vinasse and soy, corn, wheat and rice agricultural waste, carried out with the goal of identifying locations in Brazil with the greatest potential for biogas production (hotspots).

Table 47 – Potential for biogas production in each hotspot and main substrates

HOTSPOT	BIOGAS (mm³/YEAR)	MAIN SUBSTRATES
1	2,781.5	Animal manure, soy straw, corn straw, vinasse, wheat straw
2	1,778.3	Vinasse, soy straw, corn straw, animal manure
3	1,802.5	Vinasse, soy straw, animal manure, corn straw
4	1,767.8	Vinasse, soy straw, corn straw, animal manure

Source: the author.

When determining the region, it is also important to consider the seasonal crops that produce waste to ensure that biomass will be available throughout the year. This allows for the steady production of biogas over the year. The following tables show the seasons of selected crops in the regions of the identified hotspots, showing the complementary crops according to harvest seasons over the year.

Table 48 – Harvest seasons of the main crops analyzed in the Midwest region

MIDWEST												
MONTH												
CROP	JAN.	FEB.	MAR	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
Soy												
Corn 1st harvest												
Corn 2nd harvest												
Wheat												
Rice												
Sugarcane/vinasse												

Source: the author.

Table 49 – Harvest seasons of the main crops analyzed in the South regionl

SOUTH												
MONTH												
CROP	JAN.	FEB.	MAR	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
Soy												
Corn 1st harvest												
Corn 2nd harvest												
Wheat												
Rice												
Sugarcane/vinasse												

Source: the author.

In view of this, co-digestion can make use of the high energy potential of agricultural waste for biogas production, addressing the challenges associated with season production. Among the main benefits of the technology, we can cite increased biogas and biomethane production, process stability, dilution of inhibitory substances and balance of nutrients, among others (HAGOS et al., 2017). However, the heterogeneous nature of the substrates requires significantly different operating conditions. Thus, perfecting the technological process is fundamental to ensure the continuous and efficient production of energy products.

4.2. Scope and goals

The scope of the TAP is the development of agricultural waste co-digestion in areas with potential to expand ICLFS and crop rotation systems in Brazil, identifying promising niches for the application of the technology.[4]

The goal of the TAP is to develop a pilot application of a co-digestion plant in ICLFS and a plant in crop rotation systems, considering important Brazilian crops (such as sugarcane, soy, corn, rice and wheat) for the production of electricity, biomethane and biofertilizer by the year 2030.

Table 50 – TAP scope and goals

SCOPE	GOALS
Develop and implement a biogas project to use agricultural waste in areas with potential to expand ICLFS and crop rotation systems in Brazil.	Implement a pilot co-digestion plant in ICLFS and one in crop rotation systems, considering important Brazilian crops, for the production of electricity, biomethane and biofertilizer.

Source: the author.

4.3. Actions and activities

Critical gaps and barriers and means to overcome them

Due to the great potential for waste production, the main technology needs associated with the use of these resources to generate energy relate to improving technological processes for the development of large-scale projects and the characterization and definition of adequate pre-treatment processes for different substrates that can be used in a complementary manner according to seasonal availability.

With regard to the characterization of substrates, there are challenges associated with the heterogeneous nature of agricultural waste and the definition of pre-treatment technologies. In addition, the scarce or discontinued availability of gravimetric waste data in different regions of the country makes it difficult to map and size the market and carry out feasibility studies.

[4] Vinasse was not considered within the scope of the TAP as the vinasse biodigestion process is well developed in Brazil, although it has the limitation of seasonal production.

With respect to biogas plants, there is a need to expand the technology to larger scales and optimize processes, especially for waste co-digestion projects that use different types of substrates and, thus, require different processes, operations and maintenance.

Moreover, the season availability of waste discourages financing for alternative waste uses and makes it difficult to establish a market for biodigestion products. This is because a constant and predictable supply of waste is needed to make the projects viable and ensure the establishment of market contracts.

The main economic barrier is associated with high capital costs (Capex) and operating and maintenance (Opex) costs. These high costs, associated with both biogas plants and waste pre-treatment technologies, undermine investments and hinder the transfer of foreign technological expertise for the training of local labor.

Finally, there is a cultural barrier to the technology, resulting from several unsuccessful biodigestion projects in the past.

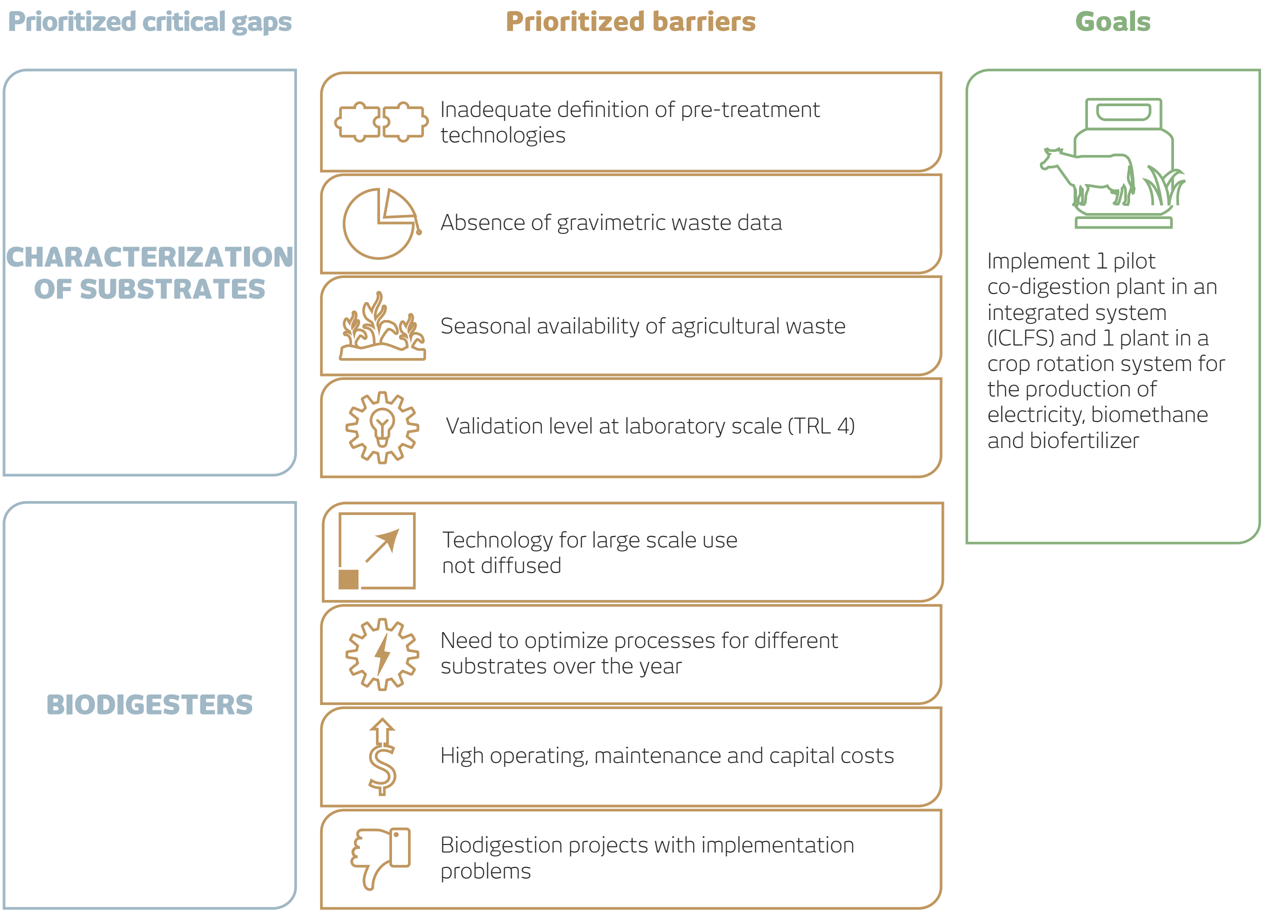


Figure 11 – Critical gaps and barriers and priority goals

Source: the author.

Actions and activities

The implementation of the TAP for the development and diffusion of co-digestion using agricultural waste comprises three interdependent actions. Action 1 involves identifying and characterizing the potential supply of raw materials for the process, with the objective of mapping potential locations for the application of the technology, thus defining the locations for the pilot plants and the waste available for co-digestion. The next step is improving knowledge on the co-digestion process through research to determine appropriate pre-treatment processes for the substrates and identify the optimal co-digestion process conditions (Action 2). Finally, pilot plants should be implemented in ICLFS and crop rotation systems, in addition to disseminating the results and knowledge obtained (Action 3).

Action 1 and related activities

Action 1 involves the identification and characterization of the potential raw material supply for co-digestion, with the goal of mapping potential locations for the application of the technology to determine the locations of the pilot plants and waste available for co-digestion.

To achieve this goal, sub-activity 1.1 consists, initially, of carrying out a detailed study, based on georeferenced data, on the availability of substrates in the country. With these results, sub-activity 1.2 seeks to identify suitable substrates, characterizing the potential supply of agricultural waste for co-digestion. Sub-activity 1.3 involves mapping the potential locations for the application of co-digestion projects, identifying the areas with an abundance of these resources. Following this, sub-activity 1.4 involves applying a multi-criteria analysis (criteria that favor the implementation of pilot plants), taking into account seasonal and general availability of substrates, proximity to research centers, favorable logistical conditions and institutional support, among others. With this, in sub-activity 1.5 it is possible to define the scale of the plants to be implemented and estimate biogas production capacity in the selected locations.

Table 51 – Action 1 and related activities

ACTION 1 – IDENTIFICATION AND CHARACTERIZATION OF THE POTENTIAL SUPPLY OF RAW MATERIAL FOR CO-DIGESTION FOR THE IMPLEMENTATION OF PILOT PLANTS	
Sub-activity 1.1	Gather data on the availability of raw material based on georeferenced data
Sub-activity 1.2	Select potential substrates for anaerobic co-digestion
Sub-activity 1.3	Identify locations with good potential for supplying raw material (agricultural waste) for biodigestion
Sub-activity 1.4	Multi-criteria selection of locations for pilot plant applications
Sub-activity 1.5	Definition of the scale of plants in the locations with the greatest technical potential for using agricultural waste

Source: the author.

Action 2 and related activities

Action 2 stems from the need for better knowledge on the co-digestion process before application in pilot plants. To achieve this, laboratory testing should investigate the substrates, pre-treatments and the different process parameters that influence the production of biogas and biomethane. Sub-activity 2.1 is aimed at performing different promising pre-treatment trials, varying some important parameters for each type of waste. Thus, the substrates selected in the previous action are pre-treated in order to determine the optimal pre-treatment process to increase the digestibility of lignocellulosic biomass.

To better understand the pre-treatment actions and their influence on biodigestion outputs, substrates should be characterized before and after pre-treatment. Data on fiber composition, carbon/nitrogen ratio (C/N), total, fixed and volatile solids and chemical oxygen demand, among other characteristics, allow for the evaluation of pre-treatment performance and provide data for sub-activity 2.3.

Sub-activity 2.3 involves performing anaerobic biodigestion tests on the different pre-treated (sub-activity 2.1) and untreated biomasses and bovine manure (both individually and combined in different proportions) under different temperature, pH and C/N ratio conditions to obtain data on biogas and biomethane production over several days. This data will help in selecting the optimal operating parameters of the plants proposed in Action 3, aimed at the best methane yields.

Table 52 – Action 2 and related activities

ACTION 2 – DEFINITION OF BIOMASS PRE-TREATMENT PROCESSES AND ANAEROBIC DIGESTION PARAMETERS	
Sub-activity 2.1	Conduct experimental research to determine the type of biomass and pre-treatment conditions
Sub-activity 2.2	Characterize waste to better understand biogas potential
Sub-activity 2.3	Conduct experimental research to establish suitable substrate compositions

Source: the author.

Action 3 and related activities

Action 3 involves the design, construction and operation of the pilot plants, in addition to the dissemination of the knowledge and results obtained.

To this end, sub-activity 3.1 involves defining the applied biodigestion system, considering the previous results. Thus, it defines the type of pre-treatment, type of biodigester and the biodigestion conditions. Following this, sub-activity 3.2 involves establishing the supply chain for the pilot units, determining the collection and transportation of raw materials.

In sub-activity 3.3, the executive project of the plants is prepared, based on the elaboration of the structural, architectural, mechanical, electrical and instrumentation design and biological processes so that the plants can then be built in sub-activities 3.4 and 3.5, according to these definitions. Sub-activity 3.4 involves the construction of a plant in ICLFS, and sub-activity 3.5 refers to the implementation of a plant in a crop rotation system. The plants should have units to receive waste, digesters with a volume of approximately 9 m3, in addition to biogas storage units, generator, digested material tank, laboratory and administration office.

Sub-activities 3.6 and 3.7 are the longest in duration and involve the testing, operation and monitoring of the pilot plants in integrated (ICLFS) and crop rotation systems. Each activity addresses the plant's operational phase, in which tests are carried out according to availability of waste in each system. These activities involve pre-treatment, control of biodigester conditions, laboratory analysis for biological control of pH, CH4 and CO_2, among other important characteristics in the process. There is also the administration and maintenance of the plant, contracting a specialized team to monitor the implementation of the units and treatment of the digestate, so that it can be used as fertilizer.

It should be emphasized that co-digestion technology in Brazil is at the technology readiness level of validation on a laboratory scale (TRL 4). The implementation of the two pilot plants would allow for the application of co-digestion in an operational environment (TRL 7).

Sub-activity 3.8 involves the dissemination of the pilot application results. To this end, a communication plan and a website for the dissemination of results should be implemented, with the production of digital content and print publications reporting project results.

Table 53 – Action 3 and related activities

ACTION 3 – IMPLEMENTATION OF THE PILOT PLANTS AND DISSEMINATION OF RESULTS	
Sub-activity 3.1	Define the biodigestion system to be implemented
Sub-activity 3.2	Establish the supply chain for the pilot units
Sub-activity 3.3	Prepare the executive project for the pilot plants
Sub-activity 3.4	Construction of a pilot plant in an integrated system (ICLFS)
Sub-activity 3.5	Construction of a pilot plant in a crop rotation system
Sub-activity 3.6	Testing, operation and monitoring of the pilot plant in an integrated system (ICLFS)
Sub-activity 3.7	Testing, operation and monitoring of the pilot plant in a crop rotation system
Sub-activity 3.8	Dissemination of the pilot plant results

Source: the author.

4.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

For the TAP to be successful in its implementation, it is important that it bring together the expertise of different stakeholders from the public and private sector, associations and representative entities.

The MCTI and MAPA could assume the coordination of the Plan, since they both promote scientific and technological research and are involved with the agricultural sector. Alternatively, the actions could be carried out by private entities, which would be responsible for the execution of the TAP.

For all actions, technical coordination and contracting partners with experience in the activities is necessary. Technical coordination could be carried out by institutions such as CIBiogás and Embrapa, in addition to universities and research centers that could contribute, especially, to implementing Actions 1 and 2. Action 2, which requires laboratory research, could benefit from the participation of physical-chemical analysis laboratories. The technical coordination of the activities in Action 3 should involve consulting and engineering companies in the renewable energy sector.

The ME could play a role in mobilizing stakeholders in the financial sector, with Finep, CNPq, Embrapii and BNDES as potential TAP financing agencies.

Given their extensive experience with studies on energy generation from waste, the EPE and Abiogás could be mobilized to assist the coordinating institutions in validating the TAP results. Finally, it is important to involve municipal governments to mobilize local stakeholders to implement the pilot units.

Table 54 – Main stakeholders to involve in the implementation of the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
MCTI	The MCTI is involved in the following areas: national telecommunications policy, scientific and technological research, information technology and automation, among others. Given its expertise, and considering the technology diffusion objective of the TAP, it could act in coordinating the implementation of actions.
MAPA	MAPA is responsible for the management of public policies to promote agriculture and agribusiness and for the regulation and standardization of services in the sector. Given its involvement in the agricultural sector, it could coordinate the implementation of TAP actions in conjunction with the MCTI.
Embrapa	Embrapa provides R&D and innovation solutions for the sustainability of agriculture for the benefit of Brazilian society. It could be responsible for coordination or act as a technical partner for the execution of TAP Action 2 activities.
CIBiogás	CIBiogás is a science, technology and innovation institution that promotes the management of organic waste as a renewable energy source. It could act in the technical coordination and/or the execution of sub-activities 1.1 to 1.5 and 3.8. Finally, it could also be the target group for sub-activity 3.8.
Universities, research centers and physical-chemical analysis laboratories	They could be involved in the development of research and laboratory analysis of waste and processes for the implementation of the TAP actions. They could act in the coordination or as technical partners in Actions 1 and 2. In addition, they could provide staff for the permanent project team.
ME	The ME is responsible for the formulation and execution of the national economic policy and the financial administration of the State. It could act in the mobilization of financing agencies to promote the TAP.

continues

continuation

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Finep	The Financier of Studies and Projects promotes science, technology and innovation in companies, universities, technological institutes and other public and private institutions. It participates throughout the innovation chain, focusing on strategic, structural and impact actions for the sustainable development of Brazil. It could act as a financing agency for TAP activities
BNDES	BNDES is the main Federal Government instrument for long-term financing and investments in all segments of the Brazilian economy. It could act as a financing agent for TAP activities.
CNPq	CNPq promotes and fosters scientific and technological development in Brazil and contributes to the formulation of national science and technology policies. It could act to support the promotion of TAP activities.
Embrapii	Embrapii provides support for technological research institutions to carry out technology research development projects for innovation in cooperation with companies in the industrial sector. It could play a role in activities to promote the TAP.
EPE	The Energy Research Company (EPE) is dedicated to the study of biofuels and is responsible for coordinating, guiding and monitoring the activities of studies on biofuels infrastructure, supply, production, transformation and commercialization, as well as studies on national and international biofuel industries. It could assist the coordinating institutions in validating the results of the TAP.
Abiogás	The Brazilian Biogas Association (Abiogás) acts as a channel for dialogue between civil society, Federal and State Governments, independent bodies and agencies responsible for Brazilian energy planning. Its goal is to transform electric, fuel and thermal energy into widely used energy commodities, with a 10% share in the Brazilian energy matrix. It could assist the coordinating institutions in validating the TAP results and, importantly, be a target group of sub-activity 3.8
Engineering companies with experience in the sector	Engineering companies in the renewable energy sector and developing anaerobic biodigestion projects could play a role in the technical coordination of the TAP and be responsible for the implementation of sub-activities 3.1 to 3.7.
Municipal governments	They could be involved in mobilizing local stakeholders to implement the pilot units, as well as being the target group of sub-activity 3.8.

Source: the author.

Schedule of actions and activities

The time frame for implementing the action plan is nine years, a time believed adequate for the development of the activities. Action 1 has one year to map and generate data on the potential availability of substrates, while Action 2 has a period of two and a half years, due to laboratory testing to better understand co-digestion processes and provide data for defining the operating parameters of the pilot plants.

Finally, Action 3, the longest in duration, has five years and six months to carry out the design, construction and operation of the two pilot plants. This is the most important stage and includes testing and monitoring the plant's operation, as well as the dissemination of results, generating more data on co-digestion aimed at encouraging new and larger projects for energy generation from agricultural waste.

It is worth noting that the activities of two plants occur in parallel, since one does not depend on the other. In addition, the activity of disseminating the results will start concurrently with the beginning of the plant's operation, with a view to facilitating and expanding the dissemination of data from the plant. The activities of the previous actions are interdependent and occur consecutively.

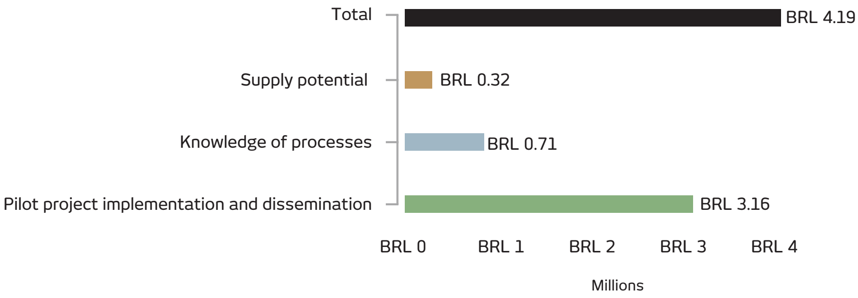
Table 55 – TAP implementation schedule

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
1.1	■																	
1.2	■																	
1.3		■																
1.4		■																
1.5		■																
2.1			■															
2.2			■	■														
2.3					■	■	■											
3.1								■										
3.2								■										
3.3									■									
3.4										■	■	■						
3.5										■	■	■						
3.6													■	■	■	■	■	
3.7													■	■	■	■	■	
3.8													■	■	■	■	■	■

Source: the author.

4.5. TAP implementation costs and financing options

The total cost for implementing the TAP was estimated at BRL 4.2 million. Action 3 (implementing the pilot plants and disseminating the results) accounts for most of the costs (approximately 75%). This is followed by Action 2, aimed at better understanding the process, accounting for 17% of the budget. Finally, the action to identify the potential waste supply represents 8% of the total cost.



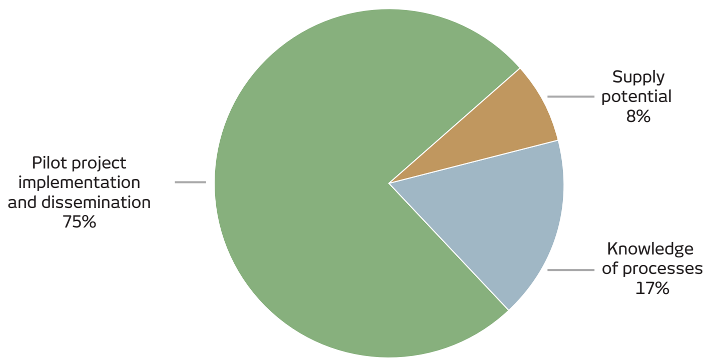


Figure 12 – Total costs, per action, in millions of BRL and as a percentage, for the agricultural waste energy TAP

Source: the author.

With respect to potential sources of financing for activities, and with a view to financial results and a focus on research and development in Actions 1 and 2, we determined the typical means of financing would be non-repayable loans and technical assistance. Financing is accessible to state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives. In the case of private entities, the actions could be executed with their own financial resources.

Action 3 could be financed through two mechanisms: repayable loans and partner equity interest. To this end, it should be emphasized that the executive project of the plant (sub-activity 3.3) should include a technical-economic feasibility study. The first means of financing (loans) is available to all stakeholders groups. Equity interest in companies, known as private equity and venture capital, involves investors obtaining a direct shareholding in the organization. With this capital, these organizations can expand and modernize their operations. Given these characteristics, it is an option restricted to small, medium and large companies.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and in the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b).

4.6. Risk and contingency plan

A summary of the potential risks associated with the implementation of the TAP activities for energy generation from agricultural waste and their respective contingency actions are shown in the table below. The following risk categories were considered: political, institutional, organizational, technical and cost risks. They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs). Finally, contingency actions were proposed to mitigate these risks.

The highest risks are associated with sub-activities 3.4 and 3.5, which involve the construction phase of the pilot plants, since there are potential problems that could delay and/or impede the continuity of the project, such as lack of financing, design errors, poor economic planning and unanticipated demands. The mitigation measures include preparing a realistic budget, ensuring commitment to guarantee financial resources and reserving resources for project contingencies. For risks associated with delays or failure to deliver material and equipment, it is important to establish an agreement with authorized institutions and suppliers. In addition, agreements should be established with these institutions to avoid regulatory or legislative barriers. To mitigate technical errors in the execution of the project, we recommend contracting qualified technical staff, supervision of the construction of the plants by specialists and the creation of mechanisms to inspect the execution of the work to ensure deadlines are met and consistency with the project.

Table 56 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1 Map the availability of raw materials based on georeferenced data 1.2 Select potential waste for anaerobic co-digestion	Technical risk and organizational risk	Lack of data. Difficulty in contracting qualified labor.	Low	Gather data in conjunction with institutions and producers. Establish TCAs with institutions to obtain data. Contract labor in leading research centers in the area.
1.3 Identify locations with high potential to supply raw material (agricultural waste) for co-digestion	Technical risk and organizational risk	Errors in data analysis resulting in the selection of inappropriate locations. Difficulty in contracting qualified labor.	Low	Validate the results obtained. Contract labor in leading research centers in the area.
1.4 Multi-criteria selection of locations for pilot plants	Technical risk, institutional risk and organizational risk	Use of inadequate criteria for selecting locations. Difficulty accessing potential locations. Difficulty in contracting qualified labor. Lack of communication and involvement of government officials.	Medium	Analyze the logistics of collecting and transporting waste. Plan on-site research. Contact local agents and institutions. Contract labor in leading research centers in the area. Establish TCAs with municipal governments. Hold meeting to apply the multi-criteria methodology.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.5 Definition of the scale of the plants in the locations with the greatest technical potential for using agricultural waste	Technical risk, institutional risk and organizational risk	Calculation/sizing errors. Difficulty in contracting qualified labor. Lack of communication and involvement of government officials.	Medium	Study successful cases of biogas plants. Search for references in the scientific literature. Establish contacts with industry and national producers. Contract labor in leading research centers in the area. Establish TCAs with municipal governments.
2.1 Conduct experimental research to determine the type and conditions of biomass pre-treatment	Technical risk and organizational risk	Accidents in the performance of tests. Errors in the definition of pre-treatment processes. Negative results. Difficulty in contracting qualified labor. Difficulty purchasing consumables.	Low	Ensure that stakeholders have the necessary laboratory infrastructure to carry out the tests. Address different pre-treatment processes and conditions and control the relevant parameters. Search for references in the scientific literature and in real applications. Contract labor in leading research centers and laboratories. Carry out efficient test planning. Establish agreements with suppliers of consumables.
2.2 Characterize waste to better understand its biogas potential	Technical risk and organizational risk	Accidents in the performance of the tests. Characterization errors. Lack of necessary equipment. Difficulty in contracting qualified labor. Difficulty purchasing consumables.	Low	Ensure that stakeholders have the necessary laboratory infrastructure to carry out the tests. Contact labor in leading research centers. Carry out efficient test planning. Establish agreements with suppliers.
2.3 Conduct experimental research to establish suitable substrate compositions	Technical risk and organizational risk	Errors in defining the efficiency curve. Insufficient results. Difficulty in contracting qualified labor. Difficulty purchasing consumables.	Medium	Carry out efficient test planning to address different conditions and control the relevant parameters. Search for references in the scientific literature and in real applications. Contract labor in leading research centers. Establish agreements with suppliers of consumables.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
3.1 Define the biodigestion system to be applied	Technical risk	Errors defining the process configuration. Problems in scaling up the process.	Medium	Search for references in the scientific literature and in real applications of successful projects. Review of the biodigestion system by technical coordination and validation by a specialist.
3.2 Establish the supply chain for the pilot units	Technical risk and organizational risk	Lack of data on local conditions and means of transport and storage of waste. Lack of supplies.	Low	Analyze the seasonal availability and source of the waste. Establish TCAs with institutions to provide supplies for the pilot plants.
3.3 Elaborate the executive project of the pilot plants	Technical risk, cost risk and institutional risk	Project errors. Poor economic planning. Failure to obtain the license to operate the plants.	Medium	Data validation by a specialist. Prepare a realistic budget that includes contingency costs. Consult legal experts to obtain the business license.
3.4 Construction of a pilot plant in an integrated system (ICLFS) 3.5 Construction of a pilot plant in a crop rotation system	Financing risk, technical risk, cost risk, institutional risk and organizational risk	Lack of funding. Design errors. Poor economic planning. Demands unanticipated in the project. Lack of or delays in the delivery of necessary material or equipment. Problems with legislation.	High	Ensure commitment to guarantee financial resources and reserve resources for project contingencies. Contract qualified technical staff. Construction supervision by specialists. Prepare a realistic budget. Create a mechanism for monitoring the execution of the work, deadlines and consistency with the project. Establish agreements with institutions and suppliers. Establish agreements with regulatory institutions to avoid regulatory barriers (legislation).
3.6 Testing, operation and monitoring of the pilot plant in an integrated system (ICLFS) 3.7 Testing, operation and monitoring of the pilot plant in a crop rotation system	Cost risk, political risk, technical risk and institutional risk	Lack of resources to operate the pilot plants. Poor economic planning. Operational problems (scale-up). Regulatory risks.	Medium	Ensure operation of the plants after the project is completed. Prepare a realistic budget that includes contingency resources. Establish technical limits for plant operation. Establish an agreement with institutions to guarantee the operational continuity of the plants after the conclusion of the project. Establish agreements with regulatory institutions to avoid regulatory barriers (legislation).

continues

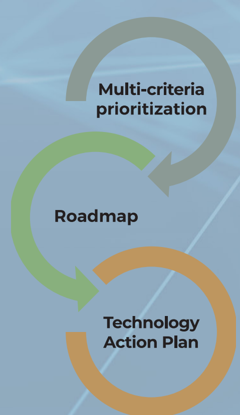
continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
3.8 Dissemination of the results of the pilot plants	Technical risk, organizational risk and institutional risk	Lack of coordination of activities and lack of qualified labor. Lack of accessibility for platform users. Failure to reach the target group. Lack of interest in maintaining the site after completing the TAP.	Medium	Contract a technical coordinator to manage and supervise activities. Contract researchers from leading centers to execute the activities. Validation of the website interface with a control group. Develop and implement a communication plan to reach the target group and provide content. Establish an agreement for transferring the platform and TCA with a higher authority (ministry) or research institute to ensure the platform is available and maintained after the project is concluded.

Source: the author.

5.

Technology Action Plan **for Photovoltaic Solar Induction Stoves**



5. TECHNOLOGY ACTION PLAN FOR PHOTOVOLTAIC SOLAR INDUCTION STOVES

5.1. Definition of technology

Solar stoves cook food using energy captured from sunlight (LIMA, 2018). In view of the ample availability of sunlight in Brazil, this technology has great potential in applications to substitute conventional biomass as a cooking fuel.

Simple solar stoves can be made with a rudimentary knowledge of the principles of solar energy and access to simple materials such as cardboard, aluminum and glass. However, the intermittency of this energy source limits its autonomy and requires the availability of other cooking alternatives. Furthermore, the low efficiency, the limited cooking options and the degradable nature of the materials make them less attractive as an alternative cooking method.

Advanced solar stoves that use integrated components, such as batteries and photovoltaic panels, solve the problems of cooking autonomy and efficiency, allowing for both the storage of larger amounts of energy for later use (batteries) and improved cooking capacity (ARAMESH et al., 2019; JOSHI; JANI, 2015).

There is a niche for the development of solar stove applications in Brazil in isolated regions and rural areas, characterized by low HDIs and lack of access to modern cooking alternatives, such as electric or gas stoves (IRENA, 2017). In these locations, traditional biomass is the only affordable cooking fuel, either purchased (when there is a local market) or collected directly in the local environment.

According to data from the *Pesquisa de Orçamento Familiar* (POF) [Family Budget Survey] of the Brazilian Institute of Geography and Statistics (IBGE), the regions with the greatest number of households in rural areas where firewood is used for cooking are the Northeast and Southeast (IBGE, 2019). The states that have the greatest number of households using wood for cooking in rural areas are Bahia, Minas Gerais and Ceará, where rural households have, on average, four residents. In addition, these states are home to the municipalities with the lowest per capita income in the country (UNDP; FJP; IPEA, 2013).

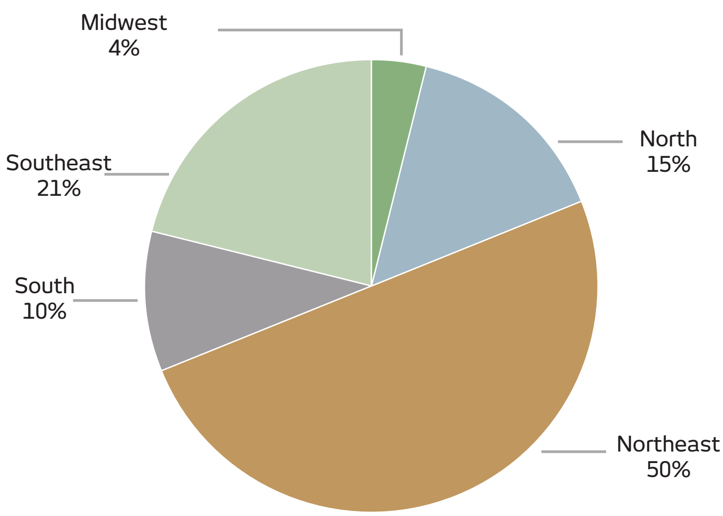


Figure 13 – Brazilian regions with the highest concentration of households in rural areas cooking with firewood

Source: the author, based on IBGE, 2019.

Given this context, the TAP for the buildings sector seeks to develop and implement advanced solar stoves in Brazil, focusing on rural households that use traditional biomass for cooking. Advanced solar stoves are induction stoves connected to batteries charged by photovoltaic panels.

This technology offers a number of economic, energy, environmental and social benefits. Among the economic benefits is the opportunity to generate income by increasing free time so people can engage in remunerated activities, since they typically spend a lot of time collecting fuel. Additional benefits are reductions in government spending on public health[5] and new business opportunities for entrepreneurs. Among the energy benefits, we can cite the increase in the use of renewable energy and improved energy security, due to self-sufficiency in the generation of energy with photovoltaic panels. Regarding social benefits, solar stoves encourage new businesses and create jobs. Finally, the environmental benefits include reductions in emissions of atmospheric pollutants, GHGs and deforestation, considering that some of the biomass used for cooking may come from native forests.

5.2. Scope and goals

In view of the above, the TAP aims to develop a project for photovoltaic solar induction stoves to reduce dependence on the availability of resources (firewood) and improve cooking efficiency. The scope of the TAP is to implement the project in isolated regions and rural areas, where traditional biomass often represents the only fuel for cooking. The selection of a more advanced type of solar stove aims to promote a relatively simple technological alternative, but one that offers energy efficiency and that can satisfy the needs of the selected population.

The goal of the TAP is to develop a prototype and pilot application of solar induction stoves to provide energy for cooking in residential buildings in regions that predominantly use traditional biomass for cooking. The goal of the prototype is to create an efficient stove that is appropriate for the Brazilian context. The pilot application seeks to overcome cultural resistance to changes in cooking behavior and provide access to the technology, as well as training for its use.

Table 57 – TAP scope and goals

SCOPE	GOALS
Develop a project for photovoltaic solar induction stoves to reduce dependence on the availability of resources (biomass) for cooking and improve cooking efficiency.	Prototype development and pilot application of solar induction stoves in residential buildings in regions with a high dependence on traditional biomass for cooking fuel.

Source: the author.

[5] The use of traditional biomass as a cooking fuel exposes users to air pollutants and toxic gases, which can lead to various health problems. Thus, the use of solar stoves contributes to the health and quality of life of the population, potentially reducing government spending on medical treatments.

5.3. Actions and activities

Critical gaps and barriers and means to overcome them

We identified 15 significant barriers to the development and diffusion of solar induction stoves in the country. Among these, we selected the barriers that, if not overcome, would prevent the diffusion of the technology, considering the project's 2030 deadline. Six critical barriers were identified to the development, diffusion and application of solar induction stoves.

Dependence on solar radiation and poor autonomy limit the use of simplified solar cookers. Hence the need to develop more efficient models, which allow for the simultaneous cooking of different foods, reach higher temperatures and have greater durability. To this end, the main technological challenge associated with the development of advanced solar stoves consists of the integration of individual components and the elaboration of a design suitable for the needs of users. These components are widely used in a number of industrial sectors.

The barriers we identified include the absence of a market with established value chains for the product, the expectation of low profitability and the increase in costs due to the inclusion of components, which may hinder its development in the country. Furthermore, cultural resistance to changes in cooking behavior and the need for user training represents another challenge for the diffusion of the technology.

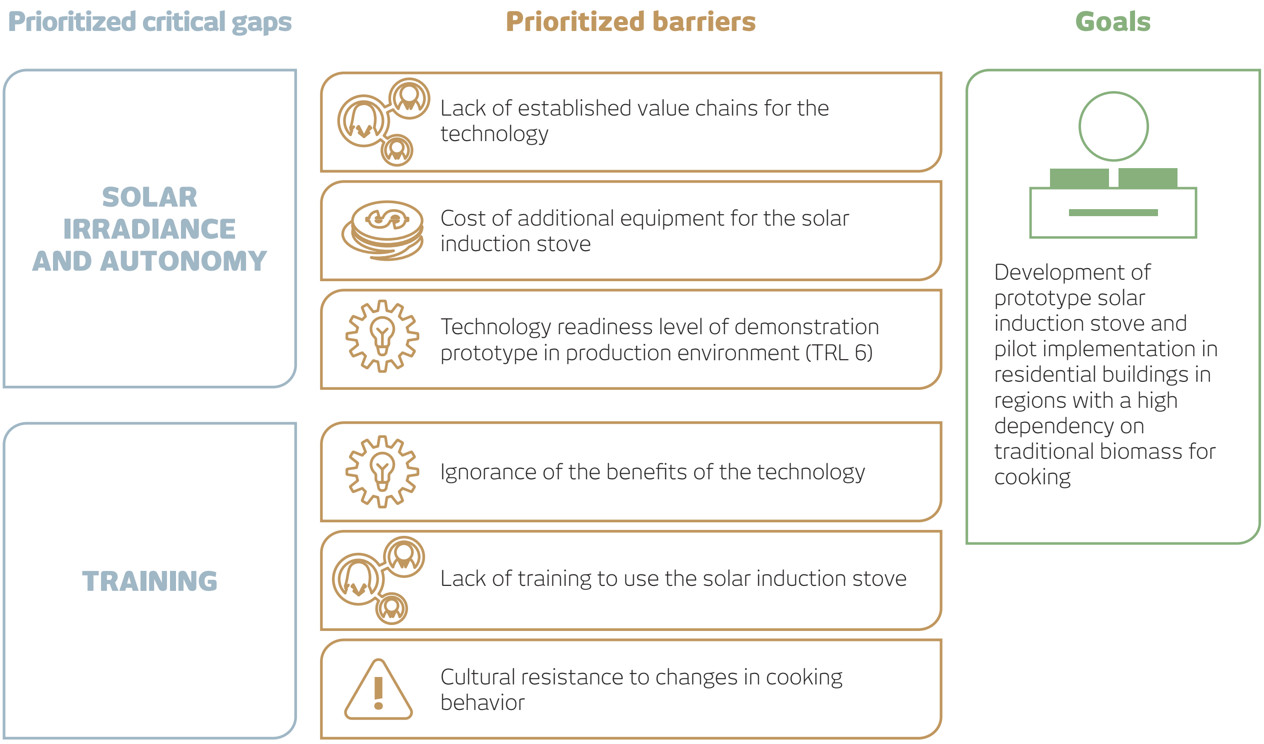


Figure 14 – Critical gaps and barriers and priority goals

Source: the author.

Actions and activities

In this section, we present the steps for executing the TAP for photovoltaic solar induction stoves. Three interdependent actions need to be implemented to achieve the goals of this TAP: design, development of the prototype, and application and dissemination of the technology.

Action 1 involves defining the design of the photovoltaic solar induction stove most appropriate for the Brazilian context. This begins with researching the models currently manufactured and available on the market and characterizing the potential location for implementation in order to define a suitable model for the local conditions. Action 2 aims to develop and test a solar stove prototype. Two models of stoves were proposed: a compact off-grid stove (500 W - 550 W one-burner induction cooktop) and a larger one (1000 W two-burner induction cooktop) that can run off the power grid. The activities in this stage involve steps for elaborating, integrating and testing the stove components. Finally, Action 3 involves the pilot application of the prototype in households in the selected location, aimed at promoting the dissemination of the pilot initiative results. In addition to manufacturing and assembling the equipment, the implementation of the prototype requires a training program to train users in the correct use of the stoves. The dissemination of the technology also includes contracting services to produce digital content, the preparation of a communication plan aimed at defining target users and a strategy for communicating the results of the pilot application, as well as demonstrating the technology at events and engagement with solar energy associations.

The definition of actions and activities, as well as the estimated costs, were based on bibliographical and market research (ARAMESH et al., 2019; COELHO et al., 2018; GIODA, 2019; JOSHI; JANI, 2015; UHLIG, 2008; SIBIYA; VENUGOPAL, 2017; ABRADI, 2020; SHE, 2017; TNO, 2020). In addition, the estimated costs consider the use of monocrystalline silicon photovoltaic panels, batteries with a storage capacity for 3 hours of use and inverters (to supply alternating current).

Action 1 and related activities

Action 1 of the TAP involves defining the design of the solar induction stove most appropriate for the Brazilian context. To achieve this, the first step is gathering data on the different models of solar stoves currently available on the international market. The parameters to be considered are the components used, efficiency and cost.

The next step is identifying potential locations to implement the solar stoves through research with a defined scope of rural regions with low per capita income where firewood is the main fuel used for cooking.

In addition, a sample survey should be conducted in households using questionnaires to identify the specific characteristics of the region, such as family income, number of residents per household, eating habits and availability of a connection to the local electricity grid. Finally, an appropriate model of solar cooker is defined based on the results obtained in the previous steps. The characteristics identified in the locations for implementation will influence the selection of a more compact off-grid model or a larger model that can run off the power grid.

Table 58 – Action 1 and related activities

ACTION 1 – DEFINITION OF THE PHOTOVOLTAIC SOLAR INDUCTION STOVE DESIGN MOST APPROPRIATE FOR THE BRAZILIAN CONTEXT	
Sub-activity 1.1	Gather data on available models of photovoltaic solar induction stoves
Sub-activity 1.2	Identification of potential locations to implement the solar induction stoves
Sub-activity 1.3	Collect data on cooking behavior in the households in the potential locations
Sub-activity 1.4	Definition of the solar induction stove design

Source: the author.

Action 2 and related activities

Action 2 of the TAP involves the development and testing of the prototype photovoltaic solar induction stove.

The first activity aims to define the type of prototype to be developed based on its application, since different types of photovoltaic solar induction stoves can be used: for example, a compact induction cooktop model for off-grid use or a larger two-burner model that can be run off the grid. For each model, it is necessary to define the technical specifications, the prototype model and simulate use in different conditions. The next activity aims to develop the photovoltaic charging system. To do this, it is necessary to select and size the photovoltaic panels, evaluate the feasibility and efficiency of different types of photovoltaic cells for the application, identify the other components of the photovoltaic system and optimize their integration in the prototypes. The choice of photovoltaic cell type directly affects the efficiency and design of the prototype. Monocrystalline silicon cells, for example, are more efficient and readily available on the market. Thin-film and organic cells are less efficient, but have the advantages of flexibility and less weight, and their performance is less affected when operating at temperatures above the nominal specified temperature. The third activity aims to develop the energy storage system for the solar induction stove prototypes. This requires sizing the batteries, selecting the other components required for the storage system and optimizing their integration in the prototypes. The fourth activity involves developing the induction system to assess the applicability and selection of the most appropriate and cost-effective induction cooktop model. This way it is possible to optimize the induction system design for better operation. Sub-activity 2.5 involves developing the necessary auxiliary components for the prototype, such as inverters, charge controllers, connectors and wiring, among others, aimed at optimizing their integration. The sixth activity involves estimating costs and integrating all the components specified in the previous steps to assemble and specify the prototype. The assembly of the prototype and all the components is carried out in the laboratory, where the technical specification of the products also occurs to determine, for example, their size, weight, autonomy and efficiency. Finally, the last activity involves testing the developed prototypes. To this end, the prototype is subjected to operation in different conditions to assess, monitor and analyze its performance.

Table 59 – Action 2 and related activities

ACTION 2 – DEVELOPMENT AND TESTING OF THE PROTOTYPE PHOTOVOLTAIC SOLAR INDUCTION STOVES	
Sub-activity 2.1	Development of the prototype according to application: compact for off-grid or larger, with a switch for the power grid
Sub-activity 2.2	Development of the photovoltaic system
Sub-activity 2.3	Development of the energy storage system
Sub-activity 2.4	Development of the induction system
Sub-activity 2.5	Development of auxiliary components: inverters, charge controllers etc.
Sub-activity 2.6	Estimation of costs and integration of components, assembly and specification
Sub-activity 2.7	Prototype operation testing

Source: the author.

Action 3 and related activities

Action 3 aims to carry out a pilot application and conduct sub-activities for the dissemination of the benefits of solar induction stove technology. The first activity aims to establish institutional and governance arrangements for the pilot application. These arrangements include authorizations from homeowners, authorizations and active participation of local institutions, including municipal governments and Regional Councils for Engineering and Agronomy (CREAs), among others. These organizations are fundamental for the successful implementation of the TAP.

The next activity is carrying out the pilot implementation of 30 solar induction stoves in the selected location (according to sub-activity 1.3). This activity consists of two stages. The first is the elaboration of a training program for the beneficiaries of the technology. The second involves the purchase, assembly and maintenance of the solar induction stove kits. The development of the training program includes the creation and preparation of the program, administering the training, and ongoing monitoring and evaluation of the program. A specialized company or individuals should carry out the purchase and installation of the components, as well as the maintenance of the stove kits.

Finally, the third activity aims to disseminate the technology and the pilot implementation results. To this end, the activity includes engagement with national and international solar energy and solar stove associations, contracting digital content services, participation in national and international conferences and events and contracting a team to prepare and implement a communication plan to reach the TAP target group.

Table 60 – Action 3 and related activities

ACTION 3 – IMPLEMENTATION AND DISSEMINATION OF THE TECHNOLOGY	
Sub-activity 3.1	Establishment of institutional, legal and project arrangements for the pilot implementation of solar induction stoves
Sub-activity 3.2	Pilot implementation of the solar induction stove prototype in 30 households in the selected location
Sub-activity 3.3	Dissemination of the benefits of the technology and pilot implementation results

Source: the author.

5.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

For the successful implementation of the TAP, for each of the proposed actions we identified stakeholders from the public and private sector, associations and representative entities, among others, who could collaborate in the implementation.

Initially, we can highlight potential TAP coordinating institutions such as the MDR and MME. Among other tasks, the MDR is responsible for formulating and implementing regional development plans and programs and establishing strategies to integrate regional economies. This Ministry also has the task of integrating different public policies for urban infrastructure and promoting regional and economic development. These responsibilities are closely aligned with the objectives of the proposed actions, especially Action 1 (identifying the location for the pilot implementation of solar induction stoves) and Action 3 (implementation and dissemination). The MME is another potential coordinating body since it is involved in energy development actions in rural areas and the establishment of national policies on the use of energy resources to promote economic, social and environmental development. Finally, companies in the solar energy sector, as well as universities and research institutes with expertise in the area, could act as coordinators or technical partners to carry out the TAP activities.

We can highlight other stakeholders with recognized expertise in the technology, or whose mission could contribute to the TAP objectives: i) potential financing agencies for TAP activities (ME, Finep, BNDES, CNPq, multilateral and development banks); ii) institutional partners that could be part of the governance structure or target group of the TAP dissemination activities (national and international solar energy associations, CNI, the Brazilian Agency for Industrial Development - ABDI, the Brazilian Electrical and Electronics Industry Association - Abinee); and iii) technical partners for specific TAP activities (National Service for Industrial Learning - Senai, IBGE, municipal governments, Engineering Associations – CREAs, and community leaders).

Table 61 – Main stakeholders to involve in implementing the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
MDR	The Ministry of Regional Development (MDR) was created in January of 2019 with the task of integrating, within a single portfolio, the various public policies for urban infrastructure and the promotion of regional and economic development. Due to the alignment between the TAP actions and the MDR's mission, this Ministry could act as a TAP coordinator.
MME	Given the MME's expertise in rural energy development and agroenergy, including rural electrification (funded with electricity sector resources), it could act as a TAP coordinator.
Finep	Finep promotes science, technology and innovation in companies, universities, technological institutes and other public and private institutions. It acts throughout the innovation chain, focusing on strategic, structural and impact actions for the sustainable development of Brazil. It could act as a financing agency for TAP activities.
BNDES	BNDES is the main Federal Government instrument for long-term financing and investment in all segments of the Brazilian economy. It could act as a financing agent for TAP activities.
CNPq	CNPq promotes and fosters scientific and technological development in Brazil and contributes to the formulation of national science and technology policies. It could act to support the promotion of TAP activities.

continues

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STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Commercial banks and multilateral development banks	Multilateral development banks are organizations formed by three or more countries with the objective of financing private and public projects and companies. Commercial banks are an important source of financing for working capital and bridge and long-term loans for energy projects. They could act as financing agencies for the TAP activities.
ME	The ME is responsible for the formulation and execution of the national economic policy and the financial administration of the State. It could act in the mobilization of stakeholders to finance TAP actions.
Universities and research groups active in the application area	These organizations are involved in activities associated with the implementation of solar energy systems, such as academic research and studies on the different areas of application of solar energy in Brazil. They could play a role in coordination or as technical partners to carry out TAP activities, especially the training for users of solar induction stoves.
Solar energy companies and manufacturers	These companies are responsible for supplying the equipment and materials for the construction of the prototype, such as photovoltaic panels, induction cooktops, energy storage systems, inverters and other auxiliary components. They could play a role in coordination or as technical partners to carry out TAP activities.
National and international solar energy associations (Absolar, CSEM, Abens, Abinee, Abeama, Abipti and SCI, among others)	These associations bring together solar energy professionals and companies across the entire production chain, including manufacturers of materials, components and equipment, component and equipment distributors and resellers, system integration companies, engineering companies, consulting, insurance and other service providers, developers, energy generators and traders, federations of industries, research centers, universities, investors and financing entities, among others. They could be part of the governance structure or be the target group of the TAP dissemination activities.
ABDI	The Brazilian Industrial Development Agency operates in strategic areas with incentive programs, investments, training and actions involving industry representatives from different sectors. It could be part of the governance structure or the target group of TAP dissemination activities.
CNI	The National Confederation of Industry represents Brazilian industry interests and promotes public policies that favor business and industrial production. It could be part of the governance structure or the target group of TAP dissemination activities.
Abinee	The Brazilian Electrical and Electronics Industry Association (Abinee) represents the electrical and electronics sector throughout Brazil, including manufacturers of equipment and components in the photovoltaic solar energy segment. It plays a role in the coordination and training of Brazilian electrical and electronics companies, acting as a facilitating agent for the strategic and tactical objectives of its associates. It could be part of the governance structure or the target group of TAP dissemination activities.
Senai	The National Industrial Training Service (Senai) is the largest private professional education complex in Latin America, active in 28 areas of Brazilian industry, providing basic professional training to technological undergraduate and graduate diplomas. It could play a role in sub-activity 3.2.
IBGE	The Brazilian Institute of Geography and Statistics (IBGE) is the main data and information provider in Brazil, serving the needs of different segments of civil society, as well as federal, state and municipal government agencies. It could play a role in sub-activities 1.2 and 1.3.
Municipal governments, Professional associations (CREAs) and community leaders	They can establish the institutional and legal arrangements and ensure social engagement in the implementation of the TAP. They could play a role in sub-activities 3.1 and 3.2.

Source: the author.

Schedule of actions and activities

The time fame for implementing the TAP is four and a half years, a time believed adequate and sufficient for the technical and financial preparations and implementation of the activities for the development and diffusion of photovoltaic solar induction stoves.

In the proposed schedule, some activities are carried out simultaneously. Sub-activities 2.1 to 2.5, for example, can be implemented concurrently, as they aim to develop the different components for the stove prototype. The successful completion of these activities directly impacts the performance of the subsequent sub-activities (2.6 and 2.7), which involve product specification and testing and, for this reason, depend on the previous results. Furthermore, in Action 3 (implementation of the pilot program), sub-activity 3.3 occurs simultaneously with the previous activity and continues until after its completion; so that there is enough time to report the results obtained.

Table 62 – TAP implementation schedule

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
1.1	■																	
1.2	■																	
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3.1						■												
3.2							■	■										
3.3							■	■	■									

Source: the author.

5.5. TAP implementation costs and financing options

The total cost of the TAP for photovoltaic solar induction stoves is estimated at BRL 2.6 million. The pilot implementation of solar induction stoves represents more than half the cost (59%), totaling approximately BRL 1.5 million. The second most expensive action involves the development of the prototype solar induction stove for the Brazilian context, totaling approximately BRL 770,000, or 29% of the budget. The activity to design the prototype best suited to the Brazilian context has the lowest cost among the TAP actions, at approximately BRL 330,000, or 12% of the total budget.

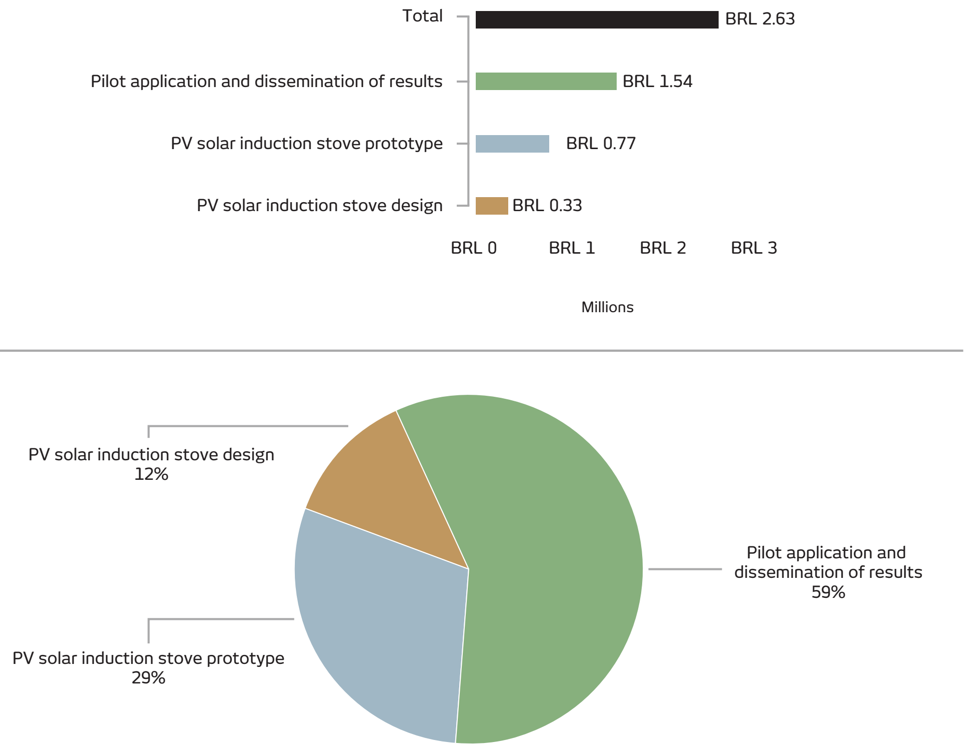

Figure 15 – Total cost per action, in millions of BRL and as a percentage, for the photovoltaic solar induction stove TAP

Source: the author.

With respect to potential sources of financing for the activities, and with a view to financial results and a focus on research and development aimed at the subsequent diffusion of the technology, we determined the typical means of financing would be non-repayable loans and technical assistance. Financing is accessible for state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and in the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b).

5.6. Risk and contingency plan

We analyzed the potential risks involved to implement the TAP activities. The following risk categories were considered: political, institutional, organizational, technical and cost risks. They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs). Finally, contingency actions were proposed to mitigate these risks.

The highest risks are associated with sub-activities 3.1 and 3.2 to establish institutional arrangements and implement the technology in 30 households. These risks are mainly associated with potential problems, including: lack of stakeholder involvement in the initiative; difficulty learning and operating the solar induction stove kit; low acceptance of the technology by the beneficiaries; installation delays; problems with the maintenance of solar induction stove kits; and the lack of technical coordination. In order to mitigate these risks, we propose contingency measures, such as: the establishment of TCAs and contracts; obtaining authorization from the electricity utility; training for users; monitoring the installation, operation and maintenance of solar stoves; and mobilizing government agencies, NGOs, regional leaders and technical staff to facilitate dialogue with the population to overcome cultural barriers, among others.

Table 63 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1 Research currently available models of photovoltaic solar induction stoves	Technical risk and organizational risk	Difficulty in accessing data, lack of technical coordination in the activity and difficulty contracting qualified labor.	Low	Establish partnerships with research centers and TCAs with relevant institutions. Prepare Terms of Reference for contracting staff for technical coordination.
1.2 Identify potential locations to implement the solar induction stoves	Technical risk and organizational risk	Errors in data analysis leading to the selection of inappropriate locations. Lack of coordination in the activity and difficulty contracting qualified labor.		Establish contracts with leading research support foundations and R&D and innovation centers for technical coordinator (defined in the Terms of Reference).
1.3 Collect data on the cooking behavior in households in the selected locations	Technical risk	Errors in data analysis leading to the selection of inappropriate locations.		Establish TCAs with relevant institutions.
1.4 Define the stove design	Technical risk and organizational risk	Definition of model not suitable for the application. Lack of coordination in the activity and difficulty contracting qualified labor.		Validation of results by competent technical staff. Establish contracts with leading research support foundations and R&D and innovation centers with expertise in the activity.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
2.1 Develop the prototypes according to application: compact off-grid for remote locations or larger cooktops, with a switch to run off the power grid	Technical risk	. Definition of model not suitable for the application.	Low	Establish partnerships with institutions to collaborate in validating the results. Ensure the support of the project technical coordination for the definition of the prototype stove.
2.2 Develop the photovoltaic system 2.3 Develop the energy storage system 2.4 Develop the induction system 2.5 Develop auxiliary components: inverters, charge controllers etc.	Technical risk, cost risk and organizational risk	Failures in the execution of activities and selection of materials, accidents in execution, breakage and difficulty sourcing equipment. Potential cost increases due to exchange rate variations that increase the cost of imported components. Potential lack of technical coordination between the stakeholders mobilized for the simultaneous development of the prototype components, resulting in delays in the activities.	Medium	Establish contracts with partner institutions with extensive expertise for carrying out the activity. Use foreign exchange hedge mechanisms for the purchase of imported components. Ensure the technical coordinator monitors compliance with deadlines and the coordination of activities. Hold regular meetings with the mobilized stakeholders. Finally, component replacement costs were estimated due to possible breakdowns.
2.6 Cost estimates and integration of components, assembly and specification	Technical risk, cost risk and organizational risk	Potential failures in the execution of the activity, equipment breakdowns, unexpected and/ or inefficient results. Potential lack of technical coordination between the stakeholders mobilized for the development of the prototype components, resulting in delays in the assembly of the prototype. Errors in cost estimates.	Medium	Establish contracts with partner institutions with extensive expertise for carrying out the activity. Establish minimum quality control parameters. Develop a feedback loop to identify any problems in the integration of components. Ensure the technical coordinator monitors compliance with deadlines and the coordination of activities. Hold regular meetings with the mobilized stakeholders. In addition, results may be validated by partner institutions and solar stove manufacturers to minimize errors in the prototype cost estimates.

continues

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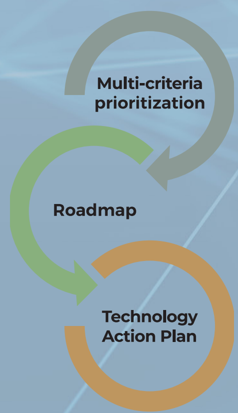
SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
2.7 Prototype operation testing	Technical risk	Failures in the execution of the activity, equipment breakdowns, unexpected and/or inefficient results.	Low	Establish minimum performance parameters for the prototype and feedback loop to identify prototype problems.
3.1 Establishment of institutional, legal and project arrangements for the pilot implementation of solar induction stoves	Institutional risk	Lack of stakeholder involvement in the initiative.	High	Establish TCAs with local municipal governments and leaders to monitor the initiative. Obtain authorization from the electricity utility and ensure supervision of the installation by a registered CREA engineer. Ensure the mobilization advisor presents the benefits of the technology to homeowners who are potential beneficiaries.
3.2 Pilot implementation of prototype solar induction stoves in 30 households in the selected location	Institutional risk, technical risk and organizational risk	Lack of stakeholder involvement in the initiative, difficulty in learning and using the solar stove kit. Low acceptance of the technology (cultural resistance). Delays in installation and lack of maintenance of solar stove kits. Lack of technical coordination in activities.	High	Establish contracts with the beneficiaries of the technology for exclusive use of the induction stove for cooking, as well as care guarantees to preserve the stove kit. Provide training and monitor the installation, use and maintenance of the solar stoves. Get constant feedback on the use of the stove kit. Ensure active monitoring of the use of solar cookers by beneficiaries. Mobilize government agents, NGOs, regional leaders and technical staff to facilitate dialogue with the population and remove cultural barriers. Contact an experienced company for the installation of the solar stoves and technical coordinator for the activities.
3.3 Dissemination of the benefits of the technology and pilot implementation results	Organizational risk	Failure to have a relevant impact on industry and organizations to stimulate interest in the technology. Lack of qualified labor to achieve the desired activity results.	Low	Mobilize different stakeholders to promote the technology and pilot implementation via easily accessible digital content. Contract professionals with extensive expertise for the production and dissemination of digital content. Establish productivity targets and access to digital content in contracts.

Source: the author.

6.

Technology Action Plan **for Innovative Materials for Cement**



6. TECHNOLOGY ACTION PLAN FOR INNOVATIVE MATERIALS FOR CEMENT

6.1. Definition of technology

Cements can be defined as the binding element that, when mixed with water and other aggregates, produces the basic materials for construction, such as concrete and mortar. Cement is the most consumed manufactured product worldwide, in terms of volume (IEA, 2018; SNIC, 2019).

However, the cement production process is responsible for a large volume of GHG emissions per unit of product, which, combined with its production on such a large scale, results in a significant share of global emissions. It is estimated that the cement industry is responsible for approximately 7% of global GHG emissions every year (SNIC, 2019).

A considerable part of these emissions is directly associated with the production of clinker, the main component of traditional Portland cement. The clinker production process consists of heating limestone to high temperatures (approximately 1400ºC) in what is termed a calcination reaction, which is the decomposition of the $CaCO_3$ molecule into CaO (the base of clinker) and CO_2. The process releases carbon dioxide into the atmosphere in the same molar ratio as it produces the desired product, which accounts for the process emissions. In addition, the high demand for energy in this stage, in particular, and in other stages of the process to a lesser extent, comes mainly from fossil fuels, which also contribute to energy-related GHG emissions. Roughly speaking, the cement process and energy-related emissions are 60% and 40%, respectively, with the latter accounting for atmospheric GHG emissions (SCRIVENER; JOHN; GARTNER, 2018; SNIC, 2019).

Thus, much of the research in the cement production sector aimed at improving environmental performance in the industry currently focuses on reducing the proportion of clinker in the final mixture that makes up Portland cement, maintaining or, if possible, improving the properties and reliability of the material.

In particular, one of the techniques widely adopted by the industry to improve the environmental performance of cement (among other objectives) is to incorporate other materials in the mixture to formulate cements with lower clinker content (generally residues from other industrial processes or abundant, low-cost substances). The Brazilian cement industry, for example, has been making ongoing efforts to reduce the clinker content in cement, moving from a clinker/cement ratio of 80% in 1990 to 67% in 2014 (SNIC, 2019).

Among these materials, known as mineral additions or supplementary cementitious materials (SCM)[6], granular blast furnace slag, coal fly ash, limestone filler and calcined clays stand out.

Granular blast furnace slag is a by-product of the pig iron process, synthesized by the rapid cooling of liquid slag, generated in the blast furnace, with specific industrial equipment for its production (SCRIVENER; JOHN; GARTNER, 2018). Brazil has been using it as an SCM for seven decades. The sector consumed 95% of all granular blast furnace slag produced in the country in 2014 (SNIC, 2019). The main barrier to increasing its use is the future availability of the material, since, even with the expected increase in production in the steel sector and the cement sector, pig iron production processes

[6] When minerals are added to cement in the plant, they are called mineral additions. When the mixing takes place outside the plant, they are considered SCMs (RIBEIRO et al., 2017).

are expected to become more efficient, resulting in a lower slag to steel ratio, compromising the availability of slag as an SCM for the cement sector (SCRIVENER; JOHN; GARTNER, 2018; SNIC, 2019).

Fly ash is a by-product of electricity generation in coal-fired thermoelectric plants. In Brazil, as thermoelectric generation is concentrated in the South region, the production of cement using fly ash as an SCM is also centralized in this region. Like the case of granular blast furnace slag, a reduction in the availability of this by-product is also expected in the future, given the global trend to decarbonize the energy sector, which should result in a decrease in thermoelectric plants globally and in Brazil (SNIC, 2019).

Fillers for cement can also be derived from the particulate particles of inert or low reactivity minerals produced in milling processes, which can be used as SCMs to reduce the ratio of clinker in cement. Limestone filler is the main type used in the cement industry since it does not require energy for calcination, only for grinding. The use of limestone filler as a substitute for clinker can reduce the carbon footprint of cement almost proportionally to the ratio of substitution of the materials. Furthermore, the addition of up to 5% limestone filler in cement can potentially improve its material properties. However, additions greater than 10% act as a physical diluent of cement and tend to reduce its mechanical resistance. This effect can be mitigated by changes in particle size and the use of chemical dispersing additives (JOHN et al., 2018).

The use of calcined clays as SCMs is a common and known practice by cement producers in Brazil, and there is an industry norm for its use as an additive for cement. However, its mitigation potential as a substitute for clinker is less than other additives, since the clay calcination process requires a lot of thermal energy, which comes from fossil fuels. Even so, there is an estimated reduction in emissions of approximately 75% compared to clinker production (SNIC, 2019).

There are also other materials that could potentially replace clinker in cement that are capable of significantly reducing the carbon intensity of cement. In Brazil, in particular, ash from burning biomass, especially sugar cane bagasse and rice husks, is generated in large quantities in the agro-industrial processing of commodities, and could be used to partially replace clinker in cement. However, there are barriers to the adoption of these materials associated with supply logistics and quality since, unlike the concentrated fly ash from coal in large thermoelectric plants, biomass ash is pulverized by individual producers that use different combustion technologies (RIBEIRO et al., 2017).

In summary, given the quantity and quality of potential clinker substitutes with well-established supply chains, we should explore these resources, especially granular blast furnace slag, coal fly ash, limestone and calcined clays, to reduce the ratio of clinker in cement in the future, especially in scenarios of increased demand for the binder. However, this poses technological challenges, both in terms of production and for the diffusion and acceptance of these new cements by a conservative construction market.

The use of SCMs has a number of associated co-benefits. From an economic point of view, it allows for cost reductions, compared to clinker. Furthermore, there is the potential to generate jobs and income with the establishment of an SCM supply chain. With respect to energy, the $CaCO_3$ calcination process to produce clinker is the stage with the highest consumption of fuels in cement production. In Brazil, petroleum coke is used as the main energy input for this process. Thus, substituting part of the clinker content in Portland cement with SCMs tends to reduce the demand for fossil fuels. The environmental benefit is a reduction in process emissions, with the same molar ratio between the addition of SCMs and the cement produced, as well as reductions in particulate matter emissions (NOx and SO_X). Finally, we can also highlight the potential reduction in impacts on biodiversity that result from less limestone mining.

In this context, we propose the TAP for innovative materials for cement. The scope and goals of the TAP are presented below.

6.2. Scope and goals

The TAP should involve different links in the cement value chain. It begins with a better understanding of the potential supply of alternative raw materials for new cement formulations with a lower clinker content, including the laboratory development of new products that are reliable in terms of technical, economic and environmental performance for the production of new cements on an industrial scale. Finally, there is the need to train users and disseminate the product and appropriate techniques for its efficient use.

The scope of the TAP is to develop new cements that meet current quality standards and that have a clinker content of 50% or less, with the addition of alternative materials. The goal of the TAP is to demonstrate the technical, economic and environmental viability of an innovative cement with a clinker content of 50% or less, using other abundant and low-cost raw materials by 2030.

Table 64 – TAP scope and goals

SCOPE	GOALS
Develop cements with a clinker content of 50% or less that meet quality standards, with the addition of abundant alternative materials.	Demonstrate the technical, economic and environmental feasibility of an innovative cement with a clinker content of 50% or less, with the addition of other abundant and low-cost raw materials by 2030.

Source: the author.

6.3. Actions and activities

Critical gaps and barriers and means to overcome them

To achieve this goal, we identified critical gaps and associated barriers. We proposed a number of measures to address these barriers, which are described in the TAP actions below.

To address the critical gap in raw materials and related barriers associated with the availability and low reactivity of alternative materials for cement, we propose the prior quantification of the availability of candidate materials at the regional level (with the perspective of the scale of the cement industry) and the development and experimental analysis of new cement formulations with lower clinker content. With regard to the critical gap in production and the barrier of technical-economic uncertainties concerning new production arrangements for new cements, we propose engineering studies for process planning and a prior economic assessment. Finally, with respect to the problem of adoption by the construction sector and the barrier of conservatism and resistance to using new techniques and materials, we propose a training program for end users to promote the adequate and efficient use of new cements.

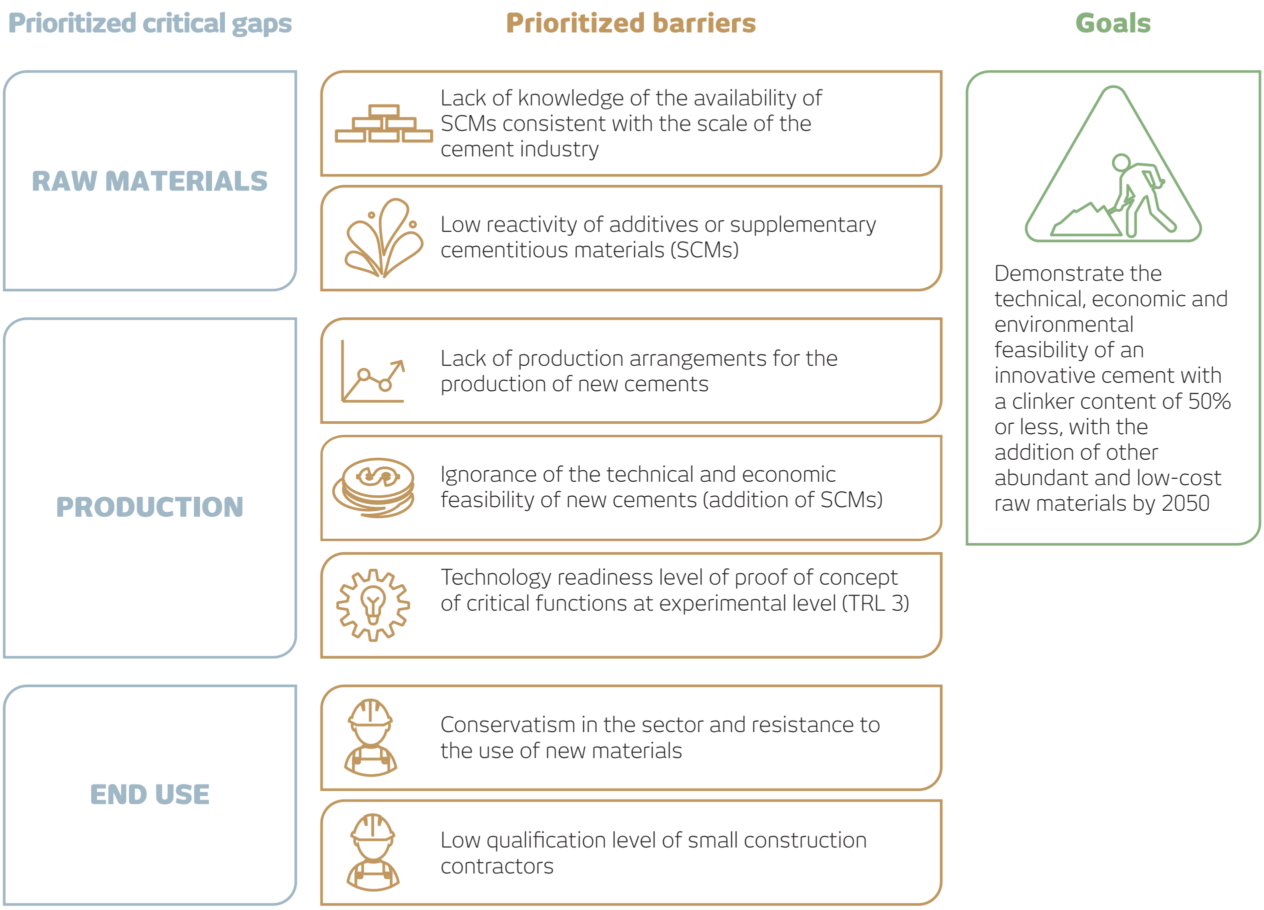


Figure 16 – Critical gaps and barriers and priority goals

Source: the author.

Actions and activities

In this subsection, we present the steps for the execution of the TAP, divided into actions and activities. The actions, developed in line with the proposed measures to address the priority barriers and the TAP scope and goals, are organized into four groups of actions: selection of potential materials for the development of new cements; product development and laboratory testing; technical, economic and environmental assessment of new cement production on an industrial scale; and training, dissemination and education for the construction sector.

The selection of potential materials involves a preliminary step for the georeferenced quantification of inputs with the potential to replace clinker in Brazil, and the cross referencing of this data with the spatial configuration of production and the cement market. This allows for the identification of zones and alternative materials to substitute clinker. The experimental development is based on these results, where one or more selected materials in the regions is taken to the laboratory for developing and testing low clinker cement formulations. Once an adequate product has been developed, a technical, economic and environmental assessment is carried out on the production process for the developed and tested innovative cement. Finally, the last action involves actions for the technological diffusion of innovative materials for cement to disseminate these innovations and train construction sector professionals with different levels of training.

Action 1 and related activities

Sub-activity 1.1 involves, initially, a review of the technical and scientific literature on alternative and abundant materials that can be used for the production of cement. This activity aims to identify materials available in Brazil with the potential to replace clinker in cement formulations.

Sub-activity 1.2 involves the quantification of the supply of the selected materials and the georeferencing of this data. For this, a regional scope compatible with the typical logistical operations of the cement industry should be considered.

Sub-activity 1.3 involves mapping the data on the current cement industry infrastructure, such as production sites and the market. This data is used for subsequent cross referencing with the supply of materials, allowing for the identification of materials and locations of interest for new cement production systems.

With these results, sub-activity 1.4 involves the selection of alternative materials with the potential to replace up to 50% of clinker in Brazil, taking into account the cement supply chains in the respective regions. This data is presented on maps, serving as the basis for selecting alternative materials for the development of new cements.

Table 65 – Action 1 and related activities

ACTION 1 – SELECTION OF ALTERNATIVE MATERIALS FOR THE DEVELOPMENT OF NEW CEMENTS	
Sub-activity 1.1	Pre-selection of potential materials to substitute clinker based on a review of the scientific and technical literature
Sub-activity 1.2	Mapping and quantifying the supply of pre-selected materials in Brazil
Sub-activity 1.3	Mapping and identification of locations of interest in the cement production chain on a regional level
Sub-activity 1.4	Selection of alternative materials to partially replace clinker in cement (new cement)

Source: the author.

Action 2 and related activities

Action 2 involves product development and laboratory testing. It starts with the planning of laboratory activities for formulating samples and testing new cements. This includes schedules, contracting staff, analyzing the demand for raw materials and using laboratory equipment to carry out the research.

After this planning stage, sub-activity 2.2 involves preparing the raw materials and mixing the components in different proportions and granulometries according to the testing program determined by the researchers. This includes grinding and mixing the samples of cement formulations containing the alternative materials selected for study, as well as storing the samples in an inert and secure place. Here, the goal of limiting clinker content to 50% should be emphasized.

With the prepared samples, it is possible to proceed to the experimental testing of each formulation. Sub-activity 2.3 includes chemical-mineralogical characterization studies to evaluate the properties of the raw materials and cements produced with the samples and formulations. The laboratory analysis in this activity involves different tests, such as insoluble residue, loss to fire, sulfur trioxide, magnesium oxide, carbon dioxide, sulfur in the form of sulfide, differential thermal analysis, thermogravimetric analysis, X-ray diffraction, electronic microscopy scanning and other tests that may be relevant.

Sub-activity 2.4 involves other laboratory tests for the physical and mechanical characterization of raw materials and products. These tests evaluate the raw materials and products obtained from the samples of formulations. The tests to measure these properties include the measurement of specific area, specific mass, fineness, expansion, curing time, consistency, resistance to compression and heat from hydration, among other tests that may reveal parameters of interest.

Following the experimental analysis, sub-activity 2.5 involves product durability tests. The objective is to test the durability and performance of the products obtained from the formulation samples, especially concrete. The laboratory tests in this activity include testing resistance to sulphate attack, acid attack and chlorides, wetting and drying cycles, natural aging, alkali-silica reaction and shrinkage, creep and rheology tests, in addition to others that may be relevant.

After these stages of experimental evaluation, sub-activity 2.6 involves the interpretation of the experimental results. In this activity, the optimal ranges of composition and granulometry of the samples are verified, based on the test results, in order to determine a formula for the new cement. The coordinators of each of the research phases should present the results and conclusions to stakeholders working in different links of the cement value chain (from production to final use) in a standardization process. This can take place in a validation workshop with invited experts and the technical teams responsible for carrying out the previous activities.

Finally, sub-activity 2.7 involves the procedures for filing a patent application for the new cement to protect intellectual property rights.

Table 66 – Action 2 and related activities

ACTION 2 – PRODUCT DEVELOPMENT AND LABORATORY TESTING	
Sub-activity 2.1	Planning of laboratory experiments
Sub-activity 2.2	Preparation of raw materials and mixing of components in different proportions and granulometries for the formulation of the samples to be analyzed, considering the limitation of 50% clinker content in the composition on a mass basis
Sub-activity 2.3	Chemical-mineralogical characterization studies of raw materials and products
Sub-activity 2.4	Physical and mechanical characterization studies of raw materials and products
Sub-activity 2.5	Product durability analysis
Sub-activity 2.6	Evaluation of the results to verify the optimum ranges of composition and granulometry of the samples and normative framework for determining the new cement formula
Sub-activity 2.7	Filing of patent application for the new cement

Source: the author.

Action 3 and related activities

Action 3 involves the technical, economic and environmental assessment for the production of new cement on an industrial scale. It starts with a front-end engineering study for a greenfield[7] production plant for the new cement (sub-activity 3.1). It involves the elaboration of a basic engineering model for a new cement production plant using the formulation defined at the end of Action 2.

Following this, sub-activity 3.2 involves a similar engineering study, but for the technical retrofitting[8] of brownfield plants aimed at determining the technical requirements to modernize a typical cement plant to produce the new cement.

Sub-activity 3.3 follows the technical studies for production and involves an analysis of the supply chain for the industrial production of the new cement in the selected locations. This activity aims to analyze the logistical issues involved in the production of the new cement in the locations identified in Action 1.

With the models for production and logistical operations identified, sub-activity 3.4 evaluates the technical, economic and environmental performance of new cement production systems, considering the cases of greenfield plant production and retrofitting existing plants.

Table 67 – Action 3 and related activities

ACTION 3 – TECHNICAL, ECONOMIC AND ENVIRONMENTAL ASSESSMENT OF NEW CEMENT PRODUCTION ON AN INDUSTRIAL SCALE	
Sub-activity 3.1	Front-end engineering study for proposing a greenfield production plant for the new cement developed in the laboratory
Sub-activity 3.2	Engineering study to technically evaluate retrofitting existing cement plants (brownfield)
Sub-activity 3.3	Analysis of the supply chain for the industrial production of the new cement in selected locations
Sub-activity 3.4	Evaluation of the technical, economic and environmental performance of the production of new cement in greenfield plants and retrofitted plants (brownfield) in the selected locations

Source: the author.

[7] A greenfield project is a new installation where there is no existing type of installation. The opposite of this is a brownfield project, which involves revamping, upgrading or modifying an existing installation.
[8] The term retrofit, in this case, means the addition of new technology in an existing installation.

Action 4 and related activities

Action 4 focuses on training personnel, disseminating technologies and education on the importance of using innovative materials in the construction sector. It aims to remove obstacles associated with the acceptance of the product in the construction market, which tends to be resistant to using new materials for cement.

Sub-activity 4.1 involves the creation and dissemination of content on innovative materials for cement and the TAP results. This requires a communication plan to define the guidelines and the target group of the digital platform to be developed. This platform will be dedicated to the dissemination of general information about new materials for cement and, principally, the TAP results.

Sub-activity 4.2 involves raising awareness, in conjunction with universities, for the inclusion of courses on innovative materials for construction in the curricula of higher education degrees in civil engineering and architecture. To this end, the activity proposes guidelines to develop elective courses in architecture and civil engineering programs in universities aimed at the dissemination of the technology for innovative materials for cement.

Finally, sub-activity 4.3 addresses the development of distance education (DE) courses in an online format aimed at teaching good practices for the construction sector. These free courses are to train workers in good practices in construction, with a focus on improving the use of cement and overcoming resistance to new cement materials.

Table 68 – Action 4 and related activities

ACTION 4 – TRAINING, EDUCATION AND DISSEMINATION FOR THE CONSTRUCTION SECTOR	
Sub-activity 4.1	Creation and dissemination of content on a digital platform for innovative materials for cement and TAP results
Sub-activity 4.2	Elaboration and dissemination of guidelines for the development of elective courses on innovative materials for cement in higher education degrees in civil engineering and architecture
Sub-activity 4.3	Development of distance education courses on good practices in construction

Source: the author.

6.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

The participation of a diverse group of stakeholders is essential for the implementation of the TAP. The involvement of stakeholders with different perspectives on the problems in the sector fosters different approaches and more efficient solutions. Thus, the identification of stakeholders to engage throughout the process improves the Plan's chance of success.

It is important to involve an institution dedicated to national scientific and technological development in the coordination, as well as leading institutions with technical expertise to carry out the actions. For the development of innovative materials for cement, the general coordination could be under the MCTI with partners from the *Rede Clima* network for the technical coordination of activities. Alternatively, the TAP could be coordinated by institutions in the cement sector, such as the SNIC and ABCP, or by an institution representing industry (CNI). These institutions and associated companies would also be instrumental in dissemination and training activities. The participation of the ME is essential to mobilize agencies to finance the Plan. In addition, Finep, BNDES, CNPq and Embrapii could participate in promoting TAP activities.

The CTIBC could play a role in the supervision of project activities, and an advisory role in validating the results. This Committee promotes cooperation between public and private bodies and entities to implement, monitor and review public policies, initiatives and projects for the transition to a low carbon economy in the Brazilian industrial sector.

Actions 1 and 3 could also be supervised by *Rede Clima* partners that are leading research centers in production engineering with experience in carrying out planning studies and technical, economic and environmental assessments. The execution of Action 2, which accounts for most of the TAP budget, should be carried out by leading technological research centers for cement linked to Brazilian universities. Additionally, the Brazilian Technical Standards Association (ABNT) could be contracted as a technical partner to prepare a proposal for standardizing the new cement. We recommend Action 4 be led by a committee of representatives of civil engineering and architecture departments of Brazilian universities, under technical partners like Senai and the Brazilian Micro and Small Business Support Service (Sebrae).

Table 69 – Main stakeholders to involve in implementing the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
MCTI	The MCTI is involved in the following areas: national telecommunications policy, scientific and technological research, information technology and automation, among others. It could act in coordinating the implementation of the TAP.
Leading research centers belonging to the *Rede Clima* network	They could act in the coordination and as technical partners for TAP actions.
ABCP	The Brazilian Portland Cement Association (ABCP) is a non-profit entity, voluntarily maintained by the Brazilian cement industry, that promotes studies on cement and its applications. It supports important Brazilian engineering projects and assists in the technology transfer process. It could act in the coordination and as a target group of TAP Action 3.

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STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
SNIC	The National Cement Industry Union (SNIC) acts as a technical and advisory body for studies and solutions for the cement industry. It could act in the coordination and as a target group of TAP Action 3.
ME	The ME is responsible for the formulation and execution of the national economic policy and the financial administration of the State. It could mobilize stakeholders to finance activities.
Finep	Finep promotes science, technology and innovation in companies, universities, technological institutes and other public and private institutions. It is involved throughout the innovation chain, focusing on strategic, structural and impact actions for the sustainable development of Brazil. It could act as a financing agent for TAP activities.
BNDES	BNDES is the Federal Government's main instrument for long-term financing and investment in all segments of the Brazilian economy. It could act as a financing agency for TAP activities.
CNPq	CNPq promotes and fosters scientific and technological development in Brazil and contributes to the formulation of national science and technology policies. It could act to support the promotion of TAP activities.
Embrapii	Embrapii provides support for technological research institutions to carry out technological research development projects for innovation in cooperation with companies in the industrial sector. It could act in activities to promote the TAP.
CTIBC	The Low Carbon Industry Technical Committee promotes cooperation between public and private bodies and entities to implement, monitor and review public policies, initiatives and projects for the transition to a low carbon economy in the Brazilian industrial sector. It could act in the supervision of project activities and play an advisory role in validating the results.
CNI	The CNI is the main representative of Brazilian industry in the defense and promotion of public policies that favor business and industrial production. It could act in the coordination and as a target group of TAP Action 3.
Construction sector representative entities and construction companies	These entities represent the interests of the sector and construction workers in Brazil, such as the Brazilian Construction Industry Chamber (CBIC), the Construction Industry Unions (Sinduscon) and the regional bodies of Civil Construction Social Services (Seconci). It also includes construction companies. They could institutionally support the execution of activities, participate in training activities (4.1, 4.2 and 4.3) and promote the dissemination of TAP results.
ABNT	The Brazilian Technical Standards Association (ABNT) could be contracted as a technical partner to develop a proposal for standardizing the new cement (sub-activity 2.6). Moreover, technicians could participate in the training activities (4.1, 4.2 and 4.3).
Senai	The National Industrial Training Service (Senai) is the largest private professional education complex in Latin America, active in 28 areas of Brazilian industry, providing basic professional training and technological undergraduate and graduate diplomas. It could act as a technical partner for Action 4.
Sebrae	The Brazilian Micro and Small Business Support Service stimulates entrepreneurship and fosters the competitiveness and sustainability of micro and small enterprises in Brazil. It could assist SENAI in coordinating Action 4.
Web design companies	These companies could be responsible for preparing the interface of the platform for the dissemina tion of information on innovative materials for cement (sub-activity 4.1).

Source: the author.

Schedule of actions and activities

The time frame for implementing the TAP is nine years, a time that is believed adequate and sufficient for the technical and financial preparation and implementation of the activities for the development of the Plan.

Action 3 can begin before the conclusion of Action 2. Specifically, the technical, economic and environmental assessment for the production of the new cement can be carried out while the patent application for the new cement is being processed (sub-activity 2.7).

Sub-activity 4.1, which involves the dissemination of the general TAP results on a digital platform, can be started as soon as the patent application is finalized.

Action 2, which accounts for the most time and budget resources, is critical for the TAP. To optimize the schedule, chemical-mineralogical (sub-activity 2.3) and physical-mechanical (sub-activity 2.4) analysis can occur in parallel, followed by product durability testing (sub-activity 2.5).

Table 70 – TAP implementation schedule

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
1.1	■																	
1.2	■																	
1.3		■																
1.4		■																
2.1			■															
2.2			■															
2.3				■	■													
2.4				■	■													
2.5						■	■	■										
2.6									■	■								
2.7										■	■	■	■	■				
3.1											■	■						
3.2												■	■					
3.3														■	■			
3.4															■	■		
4.1															■	■	■	■
4.2																	■	
4.3																■	■	■

Source: the author.

6.5. TAP implementation costs and financing options

The following are the cost estimates for the TAP, per action. The total cost was estimated at approximately BRL 5.9 million. Figure 36 shows the percentage of each action in the estimated total costs. Note that Action 2, which includes laboratory activities, accounts for most of the TAP budget.

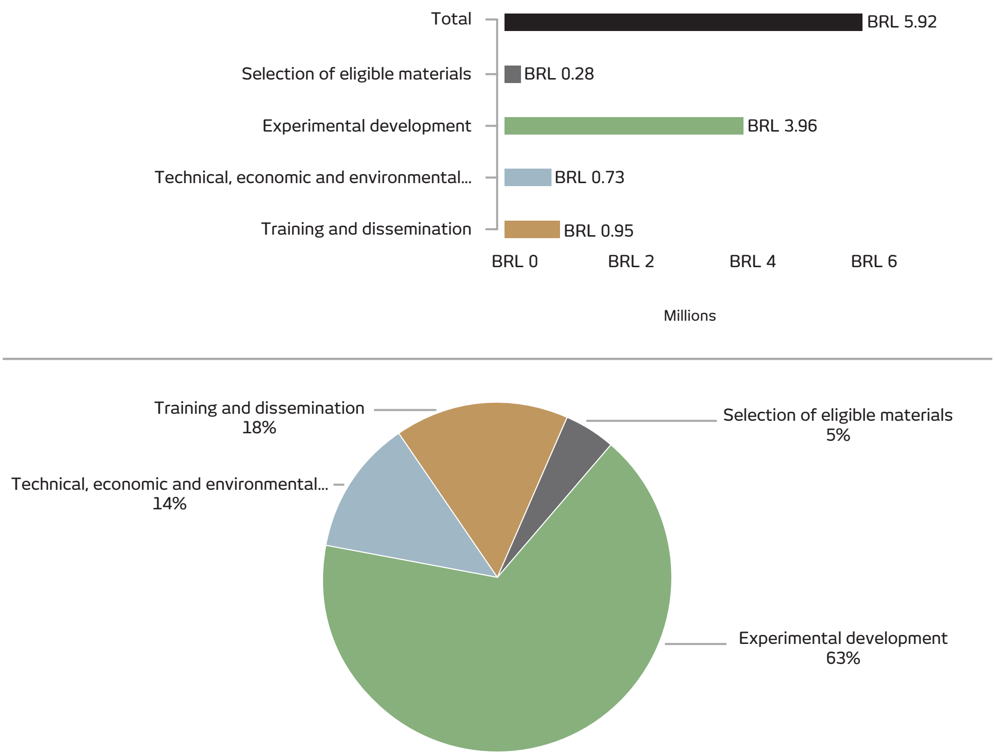

Figure 17 – Total costs, per action, in absolute amounts and as a percentage, for the innovative materials for cement TAP

Source: the author.

With respect to potential sources of financing for the activities, and with a view to financial results and the focus on research and development of new materials, we determined the typical means of financing would be non-repayable loans and technical assistance. Financing is accessible for state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and in the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b).

6.6. Risk and contingency plan

For each group of activities in each action, we analyzed the potential risks to implement the TAP activities. The following risk categories were considered: political, institutional, organizational, technical and cost risks. They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs). Finally, contingency actions were proposed to mitigate these risks.

The highest risks are associated with sub-activities 2.3, 2.4 and 2.5, which involve laboratory testing of raw materials and cement products. These risks are associated with potential laboratory accidents or delays in activities due to unplanned stoppage of critical equipment for the tests. In order to mitigate these risks, it is necessary to ensure safety procedures are followed in the execution of the experiments and foster a safe laboratory environment with an internal accident prevention committee. Other important actions are the performance of periodic maintenance, strictly following the manufacturer's instructions, and the prior planning of schedule alternatives in case of unplanned stoppage of critical equipment. Establishing contact with technical assistance, as well as previously checking the institutional bureaucratic procedures for contracting maintenance services for critical testing equipment are also measures that can mitigate potential schedule delays.

Table 71 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1 Pre-selection of potential materials to substitute clinker based on a review of the scientific and technical literature	Technical risk, organizational risk and institutional risk	Lack of data on alternative materials with the potential to replace clinker. Lack of coordination of studies and lack of qualified labor. Lack of support from key cement sector institutions.	Low	Hold a project launch event for key stakeholders. Establish TCAs with institutions that can provide data, such as SNIC and ABCP. Contract a technical coordinator with extensive expertise in the area to manage and supervise the activities and researchers from leading centers for the execution of the TAP.
1.2 Mapping and quantifying of the supply of the pre-selected materials in Brazil	Technical risk and organizational risk	Lack of accurate data on the quantity of materials available.	Low	Establish TCAs with companies in the industrial and mineral sectors that produce potential cement inputs.
1.3 Mapping to identify locations of interest in the cement production chain on a regional level	Technical risk	Error in compiling data on maps.	Low	Supervision and technical coordination of activities by specialist and validation of data processing by an external specialist.
1.4 Selection of alternative materials for partial replacement of clinker in cement (new cement)		Lack of clarity in the geographical representation of potential materials. Lack of validation of results.		

continues

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
2.1 Planning of laboratory experiments	Organizational risk and technical risk	Lack of qualified labor to carry out the formulations and tests. Lack of supervision and technical coordination for the experiments. Planning errors.	Low	Encourage periodic participation, in meetings, of the institutional partners of the network. Validate the supply model in a workshop and apply multi-criteria methodology. Find recognized partners that already have a relationship with startups and ensure support throughout the development process. Ensure the technical coordination of activities.
2.2 Preparation of raw materials and mixing of components in different proportions and granulometries for the formulation of the samples to be analyzed, considering the limitation of 50% clinker content in the composition, on a mass basis	Organizational risk and technical risk	Difficulty in developing routines for laboratory experiments. Lack of inputs to carry out all the desired formulations, causing delays in subsequent activities. Lack of supervision for the preparation of raw materials.	Medium	Supervision of laboratory activities by a specialist. Communicate with other users of multi-purpose equipment to establish routines for experiments. Prior planning of input needs and acquisition of inputs 20% over estimated consumption. Establish contacts with suppliers and verify the institutional bureaucratic procedures for the purchase of materials over the research phase.
2.3 Chemical-mineralogical characterization studies of raw materials and products	Organizational risk and technical risk	Unexpected failures of critical equipment for testing. Lack of supervision for studies. Delays in completing the activity.	High	Supervision and technical coordination of activities by specialist, with targets for the team. Carry out periodic maintenance following the manufacturer's instructions. Prior planning of schedule alternatives in case of unexpected failures of critical equipment. Establish contact with technical assistance and verify the institutional bureaucratic procedures to contract maintenance services for critical testing equipment.
2.4 Physical and mechanical characterization studies of raw materials and products	Organizational risk and technical risk	Accidents in the laboratory. Delays in completing the activity.	High	Ensure the observance of safety procedures when carrying out experiments and promote a safe laboratory environment with an internal accident prevention committee. Supervision and technical coordination of activities by specialist, with targets for the team.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
2.5 Product durability studies	Organizational risk and technical risk	Product not adequate under the current regulatory framework. Lack of validation of results by external specialists	Low	Supervision and technical coordination of activities by specialist, with targets for the team.
2.6 Evaluation of the results to verify the optimum ranges of composition and granulometry of the samples and normative framework for determining the formula of the new cement	Technical risk and institutional risk	Product not adequate under the current regulatory framework. Lack of validation of results by external specialists.	Medium	Analysis of the regulatory framework to ensure cements produced with alternative materials comply with standard NBR 16.997 / 2018. Results validation by experts.
2.7 Filing of patent application for the new cement	Organizational risk	Delays in the patent process due to bureaucratic obstacles, postponing the planned start of Action 4.	Medium	Extensive prior review of the main patent offices, focusing on Brazil, the United States and Europe. Contract a law firm specializing in patents for legal advice.
3.1 Front-end engineering study for proposing a greenfield production plant for the new cement developed in the laboratory	Technical risk, institutional risk and organizational risk	Lack of available and accessible information on industrial cement plant equipment. Lack of coordination for studies and lack of qualified labor. Use of premises that are not representative of reality in modeling processes. Lack of validation and delays in delivering the results of the activity.	Medium	Establish TCAs with institutions that can provide data. Contract a technical coordinator to manage and supervise activities and researchers from leading centers to execute the TAP actions. Supervision and technical coordination of activities by a specialist and validation of the process modeling by external specialists. Establish targets for the team.
3.2 Engineering study for the technical evaluation of retrofitting existing cement factories (brownfield)	Technical risk, institutional risk and organizational risk	Lack of available and accessible information on existing factories at the level of detail required for retrofit (brownfield) analysis. Delays in delivering the results of the activity. Lack of validation of the study.	Medium	Establish TCAs with institutions that can provide data. Establish targets for the team. Carry out the study validation in a workshop with specialists.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
3.3 Supply chain analysis for industrial production of new cement in selected locations	Technical risk, institutional risk and organizational risk	Estimate errors. Difficulty in accessing supply chain data and stakeholders. Delays in the delivery of sub-activity 1.3.	Low	Supervision and technical coordination of activities by specialist and validation of results by external specialist.
3.4 Evaluation of the technical, economic and environmental performance of the production of new cement in greenfield plants and in retrofitted plants in selected locations	Political risk and organizational risk	Contestation of results by sector stakeholders. Delays in the delivery of activities.	Low	Contract a leading research center with certified credibility. Ensure transparency in the methodology and parameters used in the calculations. Conduct validation workshops for sub-activity 3.1 to 3.3.
4.1 Creation and dissemination of content on a digital platform for innovative materials for cements and project results	Technical risk, organizational risk and institutional risk	Lack of coordination for activities and lack of qualified labor. Lack of accessibility for platform users. Failure to reach the target group. Lack of interest in maintaining the platform after completing the TAP.	Medium	Contract a technical coordinator to manage and supervise activities and researchers from leading centers for execution. Validation of the platform interface with a control group. Use dissemination methods that ensure the results reach people involved in the construction market at different levels (academia, public sector, private sector and third sector). Establish a contract for transferring the platform and TCA with a higher authority (Ministry) for the research institute to maintain the platform after the conclusion of the project.
4.2 Elaboration and dissemination of guidelines for the development of elective courses on innovative materials for cement in higher education degrees in civil engineering and architecture	Institutional risk and organizational risk	Lack of engagement by professors not used to using digital teaching resources. Difficulty in understanding the didactic objective. Difficulty contracting specialized labor.	Low	Train professors for the task of developing courses in the area and on the project results. Contract specialized labor for the process of formulating higher education proposals. Carry out engagement activities at universities.

continues

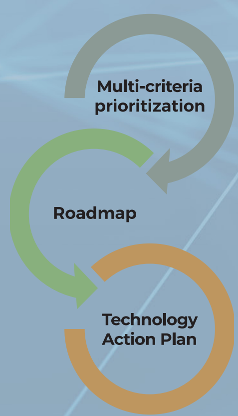
continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
4.3 Development of distance education courses on good practices in construction	Institutional risk, technical risk and organizational risk	Lack of employer interest in investing work time to train their workforce. Risks related to the quality of training programs. Difficulty contracting specialized labor.	Low	Propose incentives for employers to promote the training of workers. Simplify difficult-to-explain topics with infographics or other visual aids. Ensure ample dissemination of the course, preferably by a press professional and in digital media. Preferably, the professors from the technical teams in previous activities should teach the distance education courses.

Source: the author.

7.

Technology Action Plan **for Industry 4.0**



7. TECHNOLOGY ACTION PLAN FOR INDUSTRY 4.0

7.1. Definition of technology

Industry 4.0 is a cross-sectoral emission mitigation option for the industrial sector, as it fosters improved efficiency in the use of energy and other resources. Represented by a group of innovative technologies and a new mentality introduced with the advent of the internet, industry 4.0 allows for the internal and external integration of the production chain and the development of cyber-physical systems to support new operations and business models.

The main technologies associated with a viable 4.0 production system are described below. As it is an extensive group of technologies, the following were prioritized:

- Additive manufacturing or 3D printing: the addition of material in layers to form objects;

- Artificial intelligence: area of computing that seeks to simulate the human ability to reason, make decisions and solve problems, giving software and robots the ability to automate different processes;

- Internet of things (IoT): the connection of physical objects via the internet, enabling them to communicate and execute certain actions. An example is autonomous cars that communicate with each other and determine the best moment (using speed and trajectory, for example) to cross an intersection in a city;

- Cyber-physical systems (CPS): collaborating computational systems in contact with the physical and digital world. In this concept, every physical object (whether a machine or a production line) and the physical processes that the object controls are digitized. That is, all objects and processes in the factory have a digital "twin."

The implementation of these technologies in smart factories allows machines and inputs to share information in operations in a relatively autonomous and integrated manner. Devices located in different units of the company, or even in different companies, can also instantly share data on purchases and inventories, allowing for a degree of logistical optimization previously unthinkable, ensuring greater integration between the links of the production chain.

According to the CNI (2016), it is estimated that these new production models can result in a reduction of 10% to 40% in equipment maintenance costs, a 10% to 25% increase in labor productivity and a reduction in energy consumption between 10% and 20%.

However, in order to promote the best use of 4.0 technologies, it is necessary to advance in closing the loop of the material life cycle, in what is termed the circular economy. For Anbumozhi and Kimura (2018), the development of a circular economy requires the tools of the 4th Industrial Revolution, and you cannot have a 4th Industrial Revolution that is socially beneficial and sustainable without advancing the circular economy.

The potential benefits of integrating the circular economy and industry 4.0 technologies for the industrial sector are recognized by Brazilian industry. According to the CNI (2014), production with minimal waste creates new opportunities for industries and has wide-ranging impacts across the economy. The opportunities that arise from the circular economy and industry 4.0 can be seen in a number of examples, such as: i) production flexibility with 3D printing, which reduces and optimizes the use of resources; ii) the tracking of production and logistics with IoT, which allows for the integration of plants and shared production and logistical infrastructure; iii) increased production efficiency and recycling with the use of advanced robotics; and iv) horizontal and vertical integration using artificial intelligence, big data and IoT with instantaneous access to critical data and decision making.

7.2 Scope and goals

The TAP for industry 4.0 aims to integrate industry 4.0 techniques and technologies and the circular economy to improve the competitiveness of Brazilian industry.

The goal of the TAP is to carry out research, development, innovation, training and infrastructure actions in industry 4.0 and circular economy techniques and technologies in a Network in three strategic areas: i) technological development, through the promotion of public tenders for large, medium and small companies and startups for the development of industry 4.0 and circular economy demonstration projects; ii) human resource management, through the development of training courses for industry professionals and educators; and iii) infrastructure, through the dissemination of regulations, technical norms and public policies for the circular economy and industry 4.0.

Thus, the TAP is aimed at generating and disseminating content on industry 4.0 and the circular economy and promoting its use for the technological and sustainable development of Brazilian industry.

Table 72 – TAP scope and goals

SCOPE	GOALS
Integrate industry 4.0 techniques and technologies and the circular economy to improve the competitiveness of Brazilian industry.	Implement the Circular Economy and Industry 4.0 Technology Network to promote research, development, innovation, training and infrastructure actions in industry 4.0 and circular economy techniques and technologies.

Source: the author.

7.3. Actions and activities

Critical gaps and barriers and means to overcome them

To understand the challenges to adopting these technological solutions for the management of materials in Brazil, we mapped the main critical gaps and barriers for the development of the technology in the country. The identified barriers were prioritized to determine the training required for the diffusion of the technology in the country, as well as to guide the actions and activities for the development of the TAP for industry 4.0.

With respect to the implementation of industry 4.0 technology, we found that these technologies go beyond functional limits and involve a number of barriers to their adoption in Brazil. One of them relates to information. A large number of industrial stakeholders are unaware of this new global production trend, which feeds into an existing technological gap in Brazilian industry with respect to external competitors. Furthermore, the absence of interoperability and data security standards also represents an obstacle, as well as the lack of qualified labor. To this, we can add the poor performance in developing hardware, software and analytics in the country.

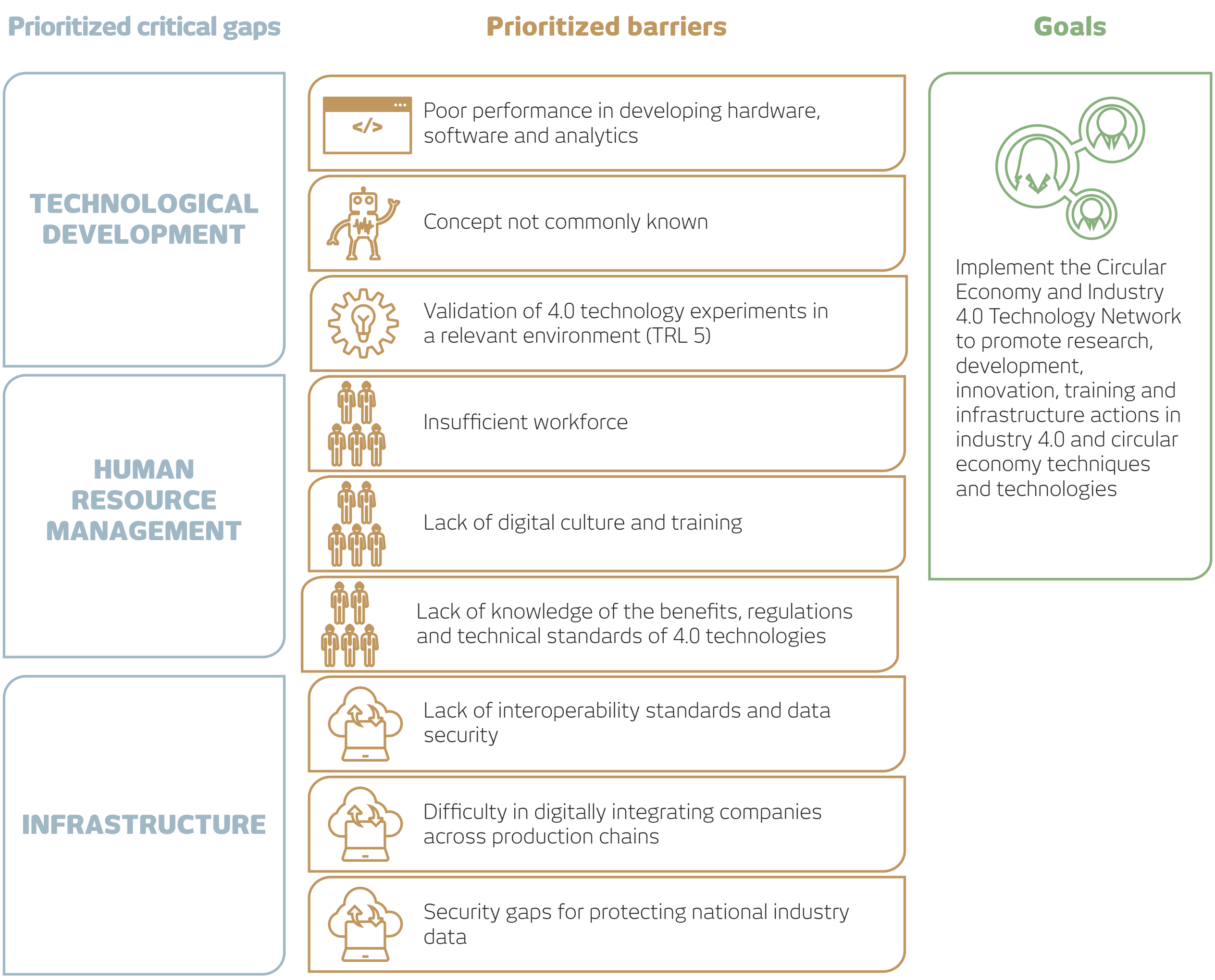


Figure 18 – Critical gaps and barriers and priority goals

Source: the author.

Actions and activities

As mentioned above, due to the cross-sectoral nature of industry 4.0 technologies and their potential applications, the TAP is organized around strategic areas of development or macro actions. The TAP involves four macro actions, each of which is composed of a group of activities and sub-activities.

The macro actions address the following areas:

1. Creation of a network with activities to promote and develop 4.0 technologies for the circular economy (Circular Economy and Industry 4.0 Technology Network);
2. Identification and development of promising 4.0 demonstration projects;
3. Training and dissemination of the knowledge generated in the demonstration projects;
4. Promotion and dissemination of regulations, technical norms and public policies for the circular economy and industry 4.0.

The first macro action is essential for the development of the following actions and is ongoing over the execution of the TAP. The development of technology, training, and promotion and diffusion of regulations and technical norms will produce strategic results and provide the Network with information for the TAP to achieve the desired scope and goals.

Macro action for the Circular Economy and Industry 4.0 Technology Network and related activities

The creation of the training Network is a central part of the industry 4.0 TAP as it provides the necessary guidelines for the promotion of this new production paradigm, which involves long-term strategic investments and bringing together various areas of expertise. Thus, the Network should coordinate and monitor the results of all the actions. There are six stages of Network activities, broken down into sub-activities.

Activity 1 involves the creation of a permanent team to coordinate the execution of the TAP actions and activities. The first action seeks to define the Network's mission, vision and values and define the short- and long-term objectives. It should be emphasized that these objectives must be in line with the strategic goals established in the TAP.

The objective of the next stage is to define the Network's activities and governance model. The identification of stakeholders should occur in parallel to the definition of Network activities, as it is understood that they are interdependent. In this phase, the macro-environment is evaluated, establishing the political-legal, economic and socio-cultural parameters, which are reflected in the patterns of preferences and technological conditions. Thus, technologies and possible applications are identified, taking into account all regions of Brazil. At the same time, potential stakeholders and institutions of the circular economy and industry 4.0 should be evaluated to create the Network Steering Committee. These stakeholders should have a history of involvement in the area and be available for ongoing involvement in the Network.

Following this, the next step is defining the Network processes (activity 3). This step consists of four sub-activities aimed, initially, at analyzing the technologies and production arrangements where the circular economy can be applied. This stage also involves the proposal of processes for qualifying, prioritizing and balancing efforts for the phase of selecting technologies and demonstration projects (sub-activity 3.1). The second step involves establishing strategies for developing demonstration projects, which should allow for the identification of potential targets for licensing, valuation, negotiation, client management, contracts, as well as innovative business models that can arise from demonstration projects. This activity is correlated to TAP activities 9, 10 and 11, and should satisfy the specificities of each activity. Following this, it is necessary to define management processes and the monitoring of contracts, establishing the project management model, rights and obligations, legal team, people responsible for monitoring the projects, deliverables and financial flows (sub-activity 3.3). Finally, it is necessary to establish the physical structure requirements for Network's processes and functions, available resources and the team required to ensure all TAP technical activities are carried out (sub-activity 3.4). It should be noted that the TAP has budgeted financial resources for all activities. However, it is up to the execution team to reassess the financial planning to carry out the TAP activities.

Once the role of the Network is structured and defined, it is necessary to establish a communication plan aimed at increasing the number of affiliates and for disseminating knowledge (activity 4). This stage involves determining the TAP target group, the most efficient communication methods to reach interested parties, general and specific communication objectives, the content approval process, available tools, action plan and the evaluation of the communication area. In addition, the Network should promote meetings to strengthen actions and foster business opportunities. This stage also involves the development of a website for external communication, as this is fundamental for attracting new investors and for monitoring the results of implemented projects. The website should include Network documents, a newsletter, online courses and training material developed by the project. The website should be maintained after it is up and running. Thus, this activity is ongoing throughout the TAP, aimed at maintaining and updating the website with content and Network results. To this end, there are financial resources allocated over the execution period to add content in a user-friendly format that facilitates navigation on the website.

Activity 5 defines the indicators for measuring and reporting the Network's performance, with two sub-activities that occur in parallel. The first involves establishing the Network reporting and evaluation plan with models for action plans, indicators, targets and correction plans to assess the Network's performance. After this step, a specialized third-party service should be contracted to assess and validate sub-activity 5.1. Best practices suggest these indicators should go through an external team to validate the process of reporting and verifying Network results. It should be noted that the TAP budget allocates resources for contracting third party services.

The last macro action activity consists of the promotion and monitoring of circular economy and industry 4.0 technology development and training actions. This is the Network's central activity and it should be ongoing over the TAP. Three sub-activities are planned, including mapping potential financing and developing the Terms of Reference for carrying out studies, research, demonstration projects and training. The Network will be responsible for stimulating the allocation of financial resources in public and private spheres for tenders in the area of circular economy and industry 4.0. Another deliverable in this activity is the management and systematization of the knowledge generated by the Network. In other words, the Network should manage the content developed, fostering interaction in the industrial sector and the dissemination of demonstration projects (activities 9, 10 and 11). Finally, the Network is expected to produce a publication on circular economy and industry 4.0. Thus, the results of the demonstration projects (subsidies for activities 9, 10 and 11) should be systematized in publications and internal Network content for dissemination. To this end, the TAP budget has resources for books and publications.

Table 73 – Macro action to establish the Circular Economy and Industry 4.0 Technology Network

MACRO ACTION 1 – ESTABLISHMENT OF A NETWORK WITH ACTIONS TO INTEGRATE INDUSTRY 4.0 TECHNOLOGIES AND THE CIRCULAR ECONOMY	
Activity 1	Definition of the Network permanent team and organizational guidelines
Sub-activity 1.1	Define the Network's mission, vision and values
Sub-activity 1.2	Establish short-, medium- and long-term goals
Activity 2	Definition of strategy, performance models and stakeholders
Sub-activity 2.1	Conduct a macro-environmental analysis, assessing political-legal, economic and socio-cultural factors, such as beliefs and values that reflect preference patterns and technological conditions
Sub-activity 2.2	Identify circular economy and industry 4.0 stakeholders and institutions to participate in the Network Steering Committee
Activity 3	Definition of Network processes
Sub-activity 3.1	Preliminary technical and business assessment of technologies and qualification, prioritization and balance of effort processes for the phase of selecting technologies and demonstration projects
Sub-activity 3.2	Definition of the business model and offer of technologies demonstrated in activities 9, 10 and 11, as well as the identification of potential targets for licensing, valuation and dissemination of technologies, negotiations and management of clients and contacts
Sub-activity 3.3	Definition of management processes and monitoring of contracts, legal team and people responsible
Sub-activity 3.4	Definition of the physical structure, available resources and the team to carry out the activities
Activity 4	Establishment of a strategy to increase the number of affiliates
Sub-activity 4.1	Establish a communication plan and agenda for holding regional and periodic meetings to discuss common interests, establish partnerships and strengthen relations
Sub-activity 4.2	Develop a website for Network documents, newsletter, online courses and training material developed in the project
Sub-activity 4.3	Maintain and update the website with content on the results of the project
Activity 5	Definition of indicators for measuring and reporting the Network's performance
Sub-activity 5.1	Definition of action plans, indicators, targets and correction plans to assess and report the performance of the Network
Sub-activity 5.2	Contract specialized third-party services to assess and validate sub-activity 5.1
Activity 6	Promotion and monitoring of circular economy and industry 4.0 technology development and training actions
Sub-activity 6.1	Map potential financing and develop Terms of Reference for carrying out studies, research, demonstration projects and training
Sub-activity 6.2	Management and systematization of the knowledge generated by the Network, promoting interaction in the industrial sector and the dissemination of demonstration projects (activities 9, 10 and 11)
Sub-activity 6.3	Prepare a publication on circular economy and industry 4.0 (subsidies for activities 9, 10 and 11) and systematize the results of the demonstration projects in publications and internal Network dissemination content

Source: the author.

Macro action for technological development and related activities

The goal of this macro action is to develop three public tenders for demonstration projects in the national industrial sector. The TAP divides the national industrial sector into three groups: large companies, startups and small and medium-sized companies. This division follows the standard adopted by the Industry 4.0 Chamber. The TAP is expected to develop projects in these three groups.

Activity 7 involves defining the technologies and segments with the greatest potential to apply resources. Activity 8 involves preparing Terms of Reference for the selection of demonstration projects in the three industrial groups mentioned above. Activities 9, 10 and 11 consist of the execution and monitoring of projects in large companies, startups and small and medium-sized companies, respectively.

The goal of activity 7 is to identify and establish partnerships in segments with the greatest potential for circular economy and industry 4.0 technological development. This activity is composed of five sub-activities initially aimed at identifying studies and preparing technical reports specifying various technological arrangements and their application in industry 4.0 and the circular economy. They seek to describe the main technologies and applications, serving as the basis of the next activities. The next step involves identifying international technology demonstration initiatives to serve as examples to support the development of solutions for the national industrial sector. This activity is aimed at the establishment of strategic partnerships for international cooperation and a greater understanding of the level of technological maturity of the available options. After carrying out an initial analysis, it is necessary to develop and validate the methodology to select segments with the greatest potential for technological development and innovation. This activity aims to ensure that resources are used efficiently, enabling the reproduction of the demonstration projects in other companies in the segment. Then, national technology demonstrators should be listed and classified, according to the maturity level of the companies. Thus, one must identify stakeholders with proven expertise in the area and assess the stage of development of the technologies. These activities are essential to understanding the current level of similar projects for the execution of activity 8. Finally, sub-activity 7.5 involves contacting the identified segments and demonstrators to bring together different stakeholders in an innovative environment that is favorable for the realization activity 8, which involves attracting stakeholders interested in participating in the Terms of Reference.

Activity 8 involves preparing sub-projects for financing, aimed at demonstrating circular economy and industry 4.0 technologies in large, medium and small companies, as well as startups. There are six sub-activities in this stage. The first step is to define the scope and requirements of the sub-projects for demonstrating technologies. To this end, it is necessary to establish the requirements to participate in the tender, selection criteria and the technical characteristics of the technological solutions desired in the three specified areas of activity. The next step involves preparing the Terms of Reference and public notices or tenders for contracting sub-projects. The goal is to prepare the text of the Term, explaining the items pointed out in the previous activity, and to submit the text to a process of evaluation and validation of the criteria and content.

It should be noted that the following selection criteria are considered a requirement for proposals: potential for mitigating GHG emissions; technical-economic feasibility study; proposition of business models for the solution; technical capacity and eligibility of the participating company; acceptance of publication of project results; concept replicability; preparation of material for training courses; and development of technical norms for communication and security.

Following this, the schedule for tenders should be launched, establishing the time between tenders and the development phases, with the Network's ability to manage parallel projects as a constraint. This activity involves clarifying doubts, as well as comprehensive dissemination to ensure market interest in submitting proposals. In the next stage, proposals are received and evaluated according to the criteria established in the Terms of Reference. In sub-activity 8.5, sub-projects are selected and contracted, ensuring that all stakeholders satisfy the prerequisites in the Terms of Reference.

Finally, the sub-project kick-off meeting is held to explain expectations and work plans for the execution of the activities, as well as addressing the doubts of partners. The intention is to establish an open and efficient partnership and communication channel with the TAP implementation stakeholders.

Activities 9, 10 and 11 are aimed at implementing the contracted projects in each segment. These activities have three sub-activities in common: i) the execution of the technology demonstration project, ensuring that the implementation and financial schedules in the project proposal are fulfilled; ii) reporting the execution status of the implementation and financial schedules and deliveries of products to the Network; and iii) reporting the results and best practices identified in the project to the Network. The contracted team must include a delivery schedule in the proposal for project results and technical deliveries. These results will be used in activity 6 of the Circular Economy and Industry 4.0 Technology Network for the dissemination of knowledge on the technologies.

Table 74 – Macro action for developing circular economy and industry 4.0 demonstration projects

MACRO ACTION 2 – IDENTIFY AND DEVELOP PROMISING DEMONSTRATION PROJECTS, ENCOURAGING PARTICIPATION AND INTERACTION IN INDUSTRY, STARTUPS, SMALL AND MEDIUM-SIZED COMPANIES AND RESEARCH CENTERS	
Activity 7	Identify and propose partnerships in segments with the greatest potential for circular economy and industry 4.0 technological development
Sub-activity 7.1	Map existing studies and identify segments, technologies and opportunities with the greatest potential for development in Brazil
Sub-activity 7.2	Identify international technology demonstration initiatives with the goal of raising awareness, inspiration, networking and benchmarking, among others
Sub-activity 7.3	Develop and validate methodology, following the example of the technological matrix, to select segments with the greatest potential for technological development and innovation
Sub-activity 7.4	List and classify national technology demonstrators, according to the maturity level of the companies
Sub-activity 7.5	Establish contacts and strategic partnerships with identified segments and demonstrators
Activity 8	Prepare sub-projects for financing aimed at demonstrating circular economy and industry 4.0 technologies in large companies, medium and small companies and startups
Sub-activity 8.1	Define the scope and requirements for sub-projects for demonstrating technologies in: i) large companies; ii) startups; and iii) small and medium-sized enterprises
Sub-activity 8.2	Prepare Terms of Reference, public notices or tenders for contracting sub-projects
Sub-activity 8.3	Launch tender schedule
Sub-activity 8.4	Receipt and evaluation of proposals
Sub-activity 8.5	Selection and contracting of sub-projects
Sub-activity 8.6	Sub-project kick-off meeting with contracted stakeholders
Atividade 9	Demonstrate circular economy and industry 4.0 technologies in large companies
Sub-activity 9.1	Execution of the technology demonstration project
Sub-activity 9.2	Reporting the monitoring of the execution of the implementation and financial schedules and product deliveries to the Network
Sub-activity 9.3	Report results and best practices identified in the project to the Network
Activity 10	Demonstrate circular economy and industry 4.0 technologies with the development of products and processes shared between startups and companies
Sub-activity 10.1	Execution of the technology demonstration project
Sub-activity 10.2	Report the monitoring of the execution of the implementation and financial schedules and product deliveries to the Network
Sub-activity 10.3	Report results and best practices identified in the project to the Network
Activity 11	Demonstrate circular economy and industry 4.0 technologies and support the participation of small and medium companies
Sub-activity 11.1	Execution of three technology demonstration projects
Sub-activity 11.2	Report the monitoring of the execution of the implementation and financial schedules and product deliveries to the Network
Sub-activity 11.3	Report results and best practices identified in the project to the Network

Source: the author.

Macro action for human resource management and related activities

The goal of the human resource management macro action is to foster circular economy and industry 4.0 competencies and skills through training and professional development courses. This macro action is subdivided into two activities.

Activity 12, the first in this group of activities, involves mapping the required technical skills (sub-activity 12.1) and stakeholders already engaged in related activities in basic, technological and higher education (sub-activity 12.2). The goal is to identify international and national studies on the inclusion of circular economy and industry 4.0 in the different phases of the education system. This is aimed at selecting and prioritizing technical competencies and skills. Another deliverable is the identification of actions and groups in Brazil working in the area to establish cooperation agreements. Finally, a portfolio of existing training on the TAP topic should be created and disseminated, including the study on competencies and skills and experiences and cases. This involves preparing material on the topic for dissemination and encouraging discussion in the education system.

The goal of activity 13 is to provide and disseminate circular economy and industry 4.0 training and technical courses (classroom and distance learning). This can be done in the following manner: first, platforms should be identified and selected for the provision of distance learning courses by conducting market research on the best platforms and practices for distance learning courses. After choosing the platform, courses and teaching material on the circular economy and industry 4.0 should be developed and made available.

Some examples of course formats and content are: "Understanding industry 4.0" and "Soft skills for industry 4.0", which are offered in their entirety and free of charge in the distance education area on the platform www.SENAI40.com.br.

Sub-activity 13.3 addresses teaching four distance education courses with a workload of 40 hours each. This requires a course schedule and a teaching agenda. All courses should issue certificates to participants, in addition to monitoring and support for students to ensure the best learning experience. This requires contracting a trained technical team to meet the quality requirements of distance education courses. Another course is planned for teachers. The innovations from industry 4.0 technologies are disruptive, which implies training teachers to better understand the topic. Thus, this activity seeks to prepare education professionals for the challenges and provide the necessary skills, as can be found in the Senai course entitled "Inspire, transform and learn: education for industry 4.0." Classroom courses on the circular economy and industry 4.0 (sub-activity 13.5) will also be offered. The goal is for students to interact and learn about the topic on a person level in a collaborative and innovative environment. This course, like the others, should issue a certificate to participants.

Finally, it is necessary to update course content and material with the advances and results of the demonstration projects (activities 9, 10 and 11). This activity aims to incorporate the Network project results in the education system. This involves the continuous updating of content and material over the project period to expand theoretical knowledge with empirical examples.

Table 75 – Macro action for human resource management and related activities

MACRO ACTION 3 – MACRO ACTION FOR HUMAN RESOURCE MANAGEMENT AND RELATED ACTIVITIES	
Activity 12	Promote circular economy and industry 4.0 competencies and skills
Sub-activity 12.1	Map the competencies and technical skills required for the circular economy and industry 4.0 for basic, technological and higher education
Sub-activity 12.2	Map initiatives focused on this area in basic, technological and higher education
Sub-activity 12.3	Create and disseminate a portfolio of existing circular economy and industry 4.0 training
Activity 13	Provide and disseminate circular economy and industry 4.0 training and technical courses (classroom and distance learning)
Sub-activity 13.1	Identify and select distance learning platforms for the provision of four courses
Sub-activity 13.2	Develop and provide courses and educational material on the circular economy and industry 4.0 similar to "Understanding industry 4.0" and "Soft skills for industry 4.0", which are 100% distance learning, free of charge and available on the platform www.SENAI40.com.br
Sub-activity 13.3	Provide four distance learning courses with a workload of 40 hours each
Sub-activity 13.4	Develop a training module on circular economy and industry 4.0 for teachers
Sub-activity 13.5	Provide training courses for teachers similar to the Senai course entitled "Inspire, transform and learn: education for industry 4.0"
Sub-activity 13.6	Develop and provide two 16-hour classroom courses for 40 students on the circular economy and industry 4.0
Sub-activity 13.7	Update course content and material with the advances and results of the pilot projects (inputs from activities 9, 10 and 11)

Source: the author.

Macro action for infrastructure and related activities

The goal of macro action 4 is to promote the establishment and diffusion of regulations and technical norms for the circular economy and industry 4.0.

It is important to note that the development of an international standard for the circular economy is currently being discussed within the scope of the International Organization for Standardization (ISO). In Brazil, the CNI is the entity heading the committee for the elaboration of this standard, as indicated by ABNT. Thus, we suggest that any new alternative rules and regulations reflect what is already being addressed in the ISO standard to avoid wasting efforts and resources on something that is underway with robust participation from the private sector. Therefore, it is important that the team for this task be aware of the advances in the norms.

Activity 14 is divided into five sub-activities. The first stage involves assessing the latest developments in: i) data management; ii) legislation; iii) technical standards for information architecture; iv) interoperability; and v) examples of information and communication infrastructure in circular economy and industry 4.0 solutions. The goal of this activity is to map current best practices, barriers and solutions.

Another task is the preparation of booklets, infographics, documents and technical notes on the topic aimed at disseminating knowledge on open and closed communication protocols, data security and international and national examples to contribute to the robustness of the data infrastructure required for the implementation and operations of the circular economy and industry 4.0. This material should be reviewed periodically, as this is an area in constant change due to the innovative nature of the technology. All material produced should be shared with companies, as determined in sub-activities 14.3 and 14.4. The first activity aims to disseminate content related to data protection and security in Brazil to foster confidence in data integration and sharing in the circular economy and industry 4.0. Companies should be aware of the opportunities, risks and protection methods involved. An example of national material is the booklet on Law No. 13.709 / 2018 - General Law for the Protection of Personal Data. Sub-activity 14.4 aims to share knowledge with companies on the best data protection legislation practices in other countries, as well as public policies to promote the circular economy and industry 4.0. The goal is to share this knowledge with the main representative associations and other stakeholders. Thus, macro action 4 provides periodic updates on the best national and international practices for data management, networks and data security.

Finally, sub-activity 14.5 aims to elaborate and disseminate proposed technical norms for architecture, interoperability and the integration of information technologies, communication and the promotion of public policies for the circular economy and industry 4.0, based on the experiences of the demonstration projects in activities 9, 10 and 11. The selected projects should make deliveries on the development of technical norms, interoperability and other functions that support the development of the Brazilian telecommunications network. The infrastructure team is responsible for systematizing the knowledge from these projects for subsequent dissemination, in compliance with the regulations discussed above.

Table 76 – Macro action for promoting and diffusing regulations, technical norms and public policies related to the circular economy and industry 4.0

MACRO ACTION 4 – PROMOTE THE ESTABLISHMENT AND DISSEMINATION OF REGULATIONS, TECHNICAL NORMS AND PUBLIC POLICIES RELATED TO THE CIRCULAR ECONOMY AND INDUSTRY 4.0	
Activity 14	Promote the establishment and dissemination of regulations, technical norms and public policies related to the circular economy and industry 4.0
Sub-activity 14.1	Assess the current best data management practices, legislation and technical standards for architecture, interoperability, integration of data and communication technologies for the circular economy and industry 4.0
Sub-activity 14.2	Prepare booklets, infographics, documents and technical notes for dissemination in sub-activities 14.3 and 14.4
Sub-activity 14.3	Share best data protection practices with companies, including the booklet for Law No. 13.709 / 2018 - General Law for the Protection of Personal Data
Sub-activity 14.4	Share best practices with companies in legislation, public policies, data protection and promotion of industry 4.0 and the circular economy in other countries
Sub-activity 14.5	Elaborate and disseminate internally the proposal for technical norms for architecture, interoperability, integration of information technology, communications and promotion of public policies for the circular economy and industry 4.0, based on the experiences of the demonstration projects in activities 9, 10 and 11

Source: the author.

7.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

For each of the four macro actions, we prospected potential stakeholders in the public and private sectors, associations and representative entities that could collaborate in the implementation of the Industry 4.0 TAP. Due to the interdependence of the macro actions, it is important to establish a general coordination body that, ideally, would act over the entire TAP schedule.

The coordination of the Circular Economy and Industry 4.0 Technology Network should be composed of members of the I4.0 Chamber, and the Chamber itself could assume the role of Network Management Committee. The Chamber was created on April 3, 2019, and involves the MCTI, ME, ABDI, CNI, Finep, CNPq, BNDES, Sebrae and Embrapii. The I4.0 Chamber Brazil action plan for 2019-2022 aims to: i) increase the competitiveness and productivity of Brazilian companies through industry 4.0; ii) improve Brazil's participation in global value chains; iii) implement industry 4.0 technologies in small and medium-sized companies; iv) provide instruments so that solutions from technology companies, startups and integrators are made available directly to companies; v) ensure stable and adequate resources, and at a reasonable cost, for the implementation of industry 4.0 initiatives; vi) identify and develop suitable industry 4.0 solutions for companies in the Brazilian industrial sector; and vii) ensure the coordination of efforts by public and private institutions to address the needs and demands of industry 4.0 in Brazil.

In view of the expertise and mission of each institution, the coordination of the Circular Economy and Industry 4.0 Technology Network macro actions and development of promising demonstration projects could be under the responsibility of the MCTI. The coordination of the human resource management action could be carried out by the CNI, while the regulation of technical norms and standards could be shared between the ME, Inmetro, MCom and Anatel. Moreover, the ME could also mobilize potential financing partners to implement the TAP, with financial support from Finep, BNDES, Embrapii and CNPq.

Given their expertise, some institutions could carry out TAP activities, such as Sebrae, ABDI, Senai, universities and research institutes and the ABNT, among others.

Table 77 – Main stakeholders to involve in implementing the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
I4.0 Chamber	In view of the objectives of the Chamber I4.0 Brazil action plan, which are aligned with the TAP macro actions, it could assume the role of Circular Economy and Industry 4.0 Management Committee.
MCTI	The MCTI is involved in the following areas: national telecommunications policy, scientific and technological research, information technology and automation, among others. It could be responsible for coordinating the Network macro actions and developing promising demonstration projects.
ME	The ME is responsible for the formulation and execution of the national economic policy and the financial administration of the State. It could be responsible for the general coordination of the regulation of technical norms and standards, as well as mobilize stakeholders to promote the TAP.
CNI	The CNI is the main representative of Brazilian industry in the defense and promotion of public policies that favor business and industrial production. It could be responsible for the technical coordination of the human resource management macro action.
MCom	The Ministry of Communications (MCom) is an organ of the Brazilian Executive Branch tasked with regulating broadcasting, postal and telecommunications services and their related entities, as well as managing national policies in related areas, such as digital inclusion. It could act in the coordination of the macro action for industry 4.0 regulations and technical norms.

continues

continuation

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Anatel	The National Telecommunications Agency (Anatel) promotes the development of telecommunications to ensure a modern and efficient infrastructure, capable of offering the public adequate, diversified services at fair prices across Brazil. It could be responsible for the technical coordination of the macro action for industry 4.0 regulations and technical norms.
Inmetro	Inmetro provides confidence for Brazilian society in measurements and products through metrology and conformity assessment, ensuring harmonious consumer relations, innovation and competitiveness in the country. It could be responsible for the technical coordination of the macro action for industry 4.0 regulations and technical norms.
Finep	Finep promotes science, technology and innovation in companies, universities, technological institutes and other public and private institutions. It operates throughout the innovation chain, focusing on strategic, structural and impact actions for the sustainable development of Brazil. It could act as a financing agent for TAP activities.
BNDES	BNDES is the main Federal Government instrument for long-term financing and investments in all segments of the Brazilian economy. It could act as a financing agent for TAP activities.
CNPq	CNPq promotes and fosters scientific and technological development in Brazil and contributes to the formulation of national science and technology policies. It could act to support the promotion of TAP activities.
Embrapii	Embrapii provides support for technological research institutions to carry out technology research development projects for innovation in cooperation with companies in the industrial sector. It could play a role in activities to promote the TAP.
Sebrae	Sebrae fosters entrepreneurship and the competitiveness and sustainability of micro and small enterprises in Brazil. It could act as a technical partner for the implementation of activities 7, 8 and 12.
ABDI	The ABDI operates in strategic areas with incentive programs, investments, training and actions involving industry representatives from different sectors. It could act as a technical partner and target group of activities 12 and 13.
Universities and research institutes	They could act as technical partners to carry out activities 7, 9, 10, 11 and, possibly, activity 13. Furthermore, they could provide qualified human resources for the TAP permanent team.
Industrial sector associations and representative organizations	They could act as specific technical partners and target group of activities 7 to 13.
Senai	Senai is the largest private professional education complex in Latin America, active in 28 areas of Brazilian industry, providing basic professional training and technological undergraduate and graduate diplomas. It could teach the courses in activity 13.
ABNT	The ABNT is the national forum for standardization. It could act as a technical partner for the execution of activity 14.
Technology solution providers	They could provide technology solutions for activities 9, 10 and 11.

Source: the author.

Schedule of actions and activities

The time frame for implementing the TAP is nine years, a time believed adequate and sufficient for the technical and financial preparation and implementation of the industry 4.0 TAP activities.

The initial activities for the creation of the Circular Economy and Industry 4.0 Technology Network are sequential, as the results from one step provide the inputs for the next phase. Some of the macro action activities are of a continuous nature, such as sub-activities 4.1 and 4.3 (communicating results) and activity 6 (promoting the other macro-actions). Hence the importance of establishing the Network for the execution of the TAP.

Studies for the elaboration of the Terms of Reference in activities 7 and 8 also take place sequentially. Activities 9, 10 and 11 can take place in parallel, depending on the Network's management capacity. Macro actions 3 and 4, for professional training and promotion of technical norms, respectively, can begin after finalizing the elaboration of the Network. The activities to update technological and regulatory advances over the project schedule should occur periodically. Furthermore, there is some interdependence between the execution activities, such as the preparation of the courses.

Table 78 – TAP implementation schedule

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
1.1	■																	
1.2	■																	
2.1	■																	
2.2	■																	
3.1		■																
3.2		■																
3.3		■																
3.4		■																
4.1			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4.2			■															
4.3				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5.1			■															
5.2			■															
6.1				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
6.2				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
6.3				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

continues

continuation

Sub-activityS	IMPLEMENTATION SCHEDULE																	
	Ano 1		Ano 2		Ano 3		Ano 4		Ano 5		Ano 6		Ano 7		Ano 8		Ano 9	
	1 SMT	2 SMT	3 SMT	4 SMT	5 SMT	6 SMT	7 SMT	8 SMT	9 SMT	10 SMT	11 SMT	12 SMT	13 SMT	14 SMT	15 SMT	16 SMT	17 SMT	18 SMT
7.1				■														
7.2				■														
7.3				■														
7.4				■														
7.5				■														
8.1					■													
8.2					■													
8.3					■													
8.4					■													
8.5					■													
8.6					■													
9.1						■	■	■	■	■	■	■	■	■	■	■	■	■
9.2						■	■	■	■	■	■	■	■	■	■	■	■	■
9.3						■	■	■	■	■	■	■	■	■	■	■	■	■
10.1								■	■	■	■	■	■	■	■	■	■	■
10.2								■	■	■	■	■	■	■	■	■	■	■
10.3								■	■	■	■	■	■	■	■	■	■	■
11.1										■	■	■	■	■	■	■	■	■
11.2										■	■	■	■	■	■	■	■	■
11.3										■	■	■	■	■	■	■	■	■
12.1				■														
12.2				■														
12.3					■													
13.1						■												
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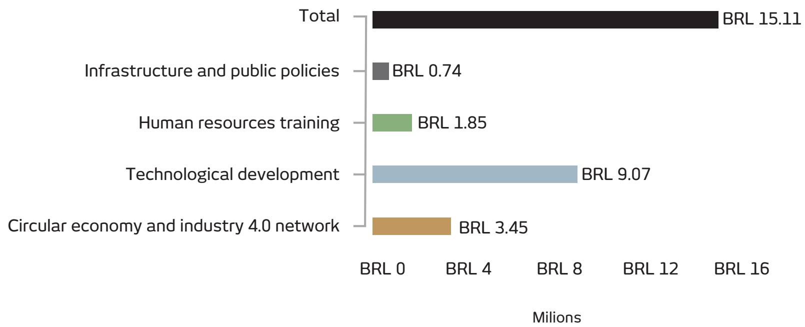
13.4									■									
13.5										■	■	■	■					
13.6														■	■			
13.7										■	■	■	■	■	■	■	■	■
14.1				■														
14.2				■		■		■		■		■		■		■		
14.3					■		■		■		■		■		■		■	
14.4					■		■		■		■		■		■		■	
14.5															■	■	■	■

Source: the author.

7.5. TAP implementation costs and financing options

The TAP implementation costs are presented by group of activities. The total cost is BRL 15.1 million, with the macro action for technological development accounting for 60% of the total, or about BRL 9.1 million. This amount is sufficient for the execution of: i) a project in large companies; ii) a project involving startups; and iii) three demonstration projects in small and medium-sized companies. The creation and maintenance of the training Network, which operates over the project's 18 semesters, represents 23% of the total cost, or BRL 3.45 million. The macro action for human resource management accounts for 12% of the budget, and infrastructure, 5%.



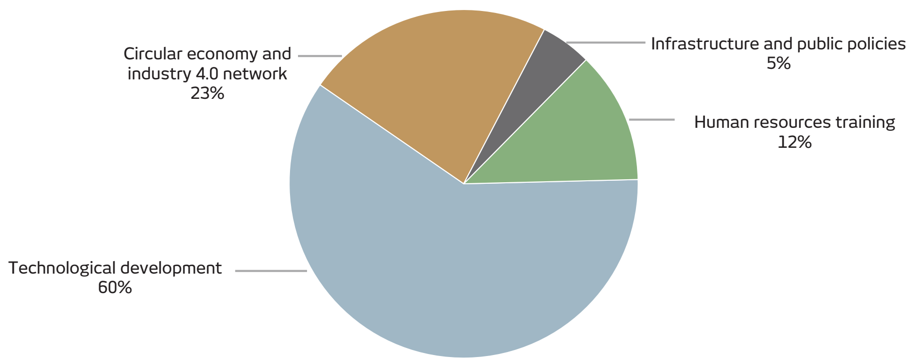


Figure 19 – Total cost per action, in millions of BRL and as a percentage, for the industry 4.0 TAP

Source: the author.

With respect to potential sources of financing for the activities, and with a view to financial results and a focus on research and development aimed at the subsequent diffusion of the technology, we determined the typical means of financing would be non-repayable loans and technical assistance. Financing is accessible for state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives.

The macro action for technological development involves the implementation of demonstration projects that should include a technical and economic feasibility study. This also makes these activities eligible for repayable loans, which are available to all groups of stakeholders.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and in the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b).

7.6. Risk and contingency plan

We analyzed the potential risks involved to implement the TAP activities. The following risk categories were considered: political, institutional, organizational, technical and cost risks. They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs). Finally, contingency actions were proposed to mitigate these risks.

The highest risks are associated with activities 9, 10 and 11. The high cost and competition for financial resources represent a threat to the development of the demonstration projects foreseen in the industry 4.0 TAP. The lack of institutional coordination also poses a high risk, as the TAP requires networked and inter-sectoral coordination. In addition to these risks, there are technical risks, such as: i) risk of contracted parties failing to fulfill obligations for various reasons; ii) poor definition of the goals and poor understanding of the technological challenges; iii) risks associated with unqualified human resources in small and medium-sized companies and employee resistance to change.

As contingency actions to mitigate these risks, we suggest that the Network make efforts to demonstrate the benefits of the TAP for both the competitiveness of the industrial sector and for progressing to a low carbon economy. Clear and strategic action by the Network is essential to ensuring the necessary financial resources. With respect to technical risks, it is necessary to assess the skills and references of contracted labor beforehand and clearly define their roles (activity 9) to ensure the success of the TAP. Activity 10 should have detailed goals for the technological challenge before it begins, with a dedicated team to address doubts and create prototypes of the final product. One way to mitigate the risks in activity 11 is to train employees in small and medium-sized companies, making them aware of the benefits of the project.

Table 79 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1 Define the Network's mission, vision and values	Institutional risk	Potential lack of executive support and commitment from superiors represents a risk in this initial phase, which requires greater stakeholder participation. There is also a risk that the parties may have conflicting interests due to different expectations for the project.	Medium	Use project management methods to harmonize the personal goals of each representative, maintaining a balance between duties over the project life cycle. Hold meetings to involve stakeholders with specific responsibilities and expertise for activities.
1.2 Establish short-, medium- and long-term goals				

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
2.1 Conduct macro-environmental analysis, assessing political-legal, economic and socio-cultural conditions, such as beliefs and values that reflect preferences and technological conditions 2.2 Identify circular economy and industry 4.0 stakeholders and institutions for the Network Steering Committee	Technical risk	High-level planning is based on assumptions, which represents a risk during the execution of the project. In addition, there is a risk of not identifying qualified coordinators and key stakeholders to lead the project.	Low	Detailed strategic planning to identify flawed assumptions, in addition to ensuring coordinators are committed to the project. Moreover, a Network Steering Committee should be created, ideally with expertise in the implementation of industry 4.0 technologies.
3.1 Preliminary technical and business assessment of technologies and proposal of qualification processes, prioritizing and balancing efforts for selecting technologies and demonstration projects 3.2 Definition of the business model and offer of technologies for demonstration in activities 9, 10 and 11, as well as identification of potential targets for licensing, valuation, dissemination of technologies, negotiation and management of clients and contacts 3.3 Definition of the management process and monitoring of contracts, legal team and people responsible 3.4 Definition of the physical structure, available resources and the team to carry out the activities	Organizational risk and technical risk	Inconsistent and conflicting requirements are potential risks when working with different organizations, as parties tend to focus on only one part of the product, and the idea of the final product is unclear. In addition, the absence of a clear division of labor is another risk in this project stage. Additionally, there is a risk of not finding qualified labor to carry out the activity.	Low	Require interested parties to fully describe the interest requirements to match expectations, analyzing their feasibility together. Ensure that the division of labor and processes are central at this stage. Finally, contract staff from leading R&D and innovation centers with proven experience in implementing research and business networks.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
4.1 Establish a communication plan and agenda for holding regional and periodic meetings to discuss common issues, establish partnerships and strengthen relations 4.2 Develop a website for Network documents, newsletter, online courses and training material developed in the project 4.3 Maintain the website and update content, based on the results of the project	Technical risk	There are communication-related risks such as not identifying the target group and goals, lack of reliable media and conflicts over content and data security, which can affect both external and internal network communication.	Low	Develop and monitor the implementation of the communication plan. Identify and rectify communication failures as soon as they are detected. Use the best communication methods, channels and protocols for sharing information. Ensure technical coordination between activities by contracting qualified labor in order to generate the desired subsidies for the website.
5.1 Define action plans, indicators, targets and correction plans to assess and report on the performance of the Network 5.2 Contract a specialized third-party service to assess and validate sub-activity 5.1	Organizational risk	Inefficient processes for project data collection and systematization, especially for the development of performance indicators and targets, in addition to delayed results from contracted labor.	Medium	Identify and rectify communication failures as soon as they are detected. Use the best communication methods, channels and protocols for sharing information. Contract an external service to validate the indicators with a company with proven expertise in reporting and verification systems for network performance.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
6.1 Map funding opportunities and develop Terms of Reference for carrying out studies, research, demonstration projects and training 6.2 Manage and systematize the knowledge generated by the Network, promoting industry interaction and the dissemination of demonstration projects (activities 9, 10 and 11) 6.3 Prepare a book on circular economy and industry 4.0 (subsidies for activities 9, 10 and 11) and systematize the results of the demonstration projects in publications and internal Network dissemination material	Political risk, technical risk and financial risk	Potential political interests and disputes over financial resources for the execution of specific TAP activities. Another risk is not attracting interested parties for the development of technological and training solutions that satisfy the prerequisites for contracting and scope.	Medium	Ensure flexibility in management so the project is a platform with different goals and objectives. Ensure Network manager representation and authority. Create a favorable pre-tender environment to attract technically qualified stakeholders.
7.1 Map existing studies and identify segments, technologies and opportunities with the greatest potential for development in Brazil 7.2 Identify international technology demonstration initiatives aimed at raising awareness, inspiration, networking and benchmarking, among others 7.3 Develop and validate methodology, following the example of the technological matrix, to select segments with the greatest potential for technological development and innovation 7.4 List and classify national technology demonstrators, according to the maturity level of the companies 7.5 Establish contact and strategic partnerships with identified segments and demonstrators	Technical risk and organizational risk	Risks associated with the lack of technical coordination and lack of qualified labor resulting in underestimating technological restrictions. In addition, there is a risk of lack of interest in establishing strategic partnerships.	Medium	Attract and contract qualified professionals. Establish review processes with feedback from a vast technical team to assess the feasibility of certain tasks and validate all requirements and specifications. Finally, establish cooperation agreements with rights and obligations for strategic parties.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
8.1 Define the scope and requirements of sub-projects for demonstrating technologies in: i) large companies; ii) startups; and iii) small and medium-sized enterprises	Political risk, cost risk and institutional risk	Competition to prioritize certain aspects may interfere with the progress of the project. Added to this is the risk of poor definition of the scope and minimum tender requirements.	Medium	Communicate with the main funding agents and contact international funding agencies. Contract a consulting team to evaluate and validate the tenders.
8.2 Prepare Terms of Reference, public notices or tenders for contracting sub-projects				
8.3 Launch tender schedule				
8.4 Receipt and evaluation of proposals				
8.5 Selection and contracting of sub-projects				
8.6 Sub-project kick-off meeting with contracted stakeholders				
9.1 Execution of the technology demonstration project	Cost risk, technical risk and institutional risk	Lack of financial resources for projects and activities 10 and 11. In addition, there is the risk of contracted parties failing to fulfill obligations for various reasons.	High	Clear and transparent Network performance and highlighting the benefits is essential to ensure the necessary financial resources. Evaluate the skills of contracted employees beforehand, checking references to ensure a reasonable success rate and ensure that the roles of contracted parties are well defined. Ensure resources for financing Circular Economy and Industry 4.0 Technology Network sub-projects.
9.2 Monitor the execution of the implementation and financial schedules and product deliveries				
9.3 Report the project results and best practices to the Network				

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
10.1 Execution of the technology demonstration project 10.2 Monitor the execution of the implementation and financial schedules and product deliveries 10.3 Report the project results and best practices to the Network	Cost risk, technical risk and institutional risk	Poorly defined goals and perception of the results of the technological challenge.	High	Develop detailed goals for the technological challenge before launch and have a dedicated team to address doubts and create prototypes of the final product. Ensure resources for financing Circular Economy and Industry 4.0 Technology Network sub-projects.
11.1 Execution of three technology demonstration projects 11.2 Monitor the execution of the implementation and financial schedules and product deliveries 11.3 Report the project results and best practices to the Network	Cost risk, technical risk and institutional risk	Lack of qualified labor in small and medium-sized companies and employee resistance to change.	High	Train employees and raise awareness of the benefits of the project. Ensure resources for financing Circular Economy and Industry 4.0 Technology Network sub-projects.
12.1 Map the competencies and technical skills required for the circular economy and industry 4.0 in basic, technological and higher education 12.2 Map circular economy and industry 4.0 initiatives in basic, technological and higher education 12.3 Create and disseminate the Circular Economy and Industry 4.0 Technology Network training portfolio	Technical risk	Lack of experience in the circular economy and industry 4.0 team.	Low	Create skill tests to contract, evaluate and assign team members to the most appropriate tasks.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
13.1 Identify and select distance learning platforms for the provision of four courses 13.2 Develop and provide courses and educational material on the circular economy and industry 4.0 similar to "Understanding industry 4.0" and "Soft skills for industry 4.0", which are 100% free distance learning courses available on the platform www.SENAI40.com.br 13.3 Conduct four distance learning courses with a workload of 40 hours each 13.4 Develop a circular economy and industry 4.0 training module for teachers 13.5 Offer training courses for teachers, similar to the Senai course entitled "Inspire, transform and learn: education for industry 4.0" 13.6 Develop and offer two 16-hour classroom courses for 40 students on the circular economy and industry 4.0 13.7 Update course content and material with pilot project advances and results (inputs from activities 9, 10 and 11)	Technical risk	Risk related to the quality of the courses and the content for dissemination.	Low	Perform quality checks in each step and, if changes are necessary, implement them immediately.

continues

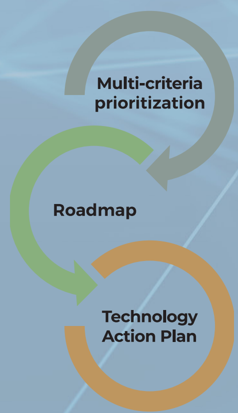
continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
14.1 Assess the current best data management practices, legislation and technical norms for architecture, interoperability, data integration and communication technologies in the circular economy and industry 4.0	Technical risk	Poor documentation of the architecture of the systems developed. Failure to consider previous initiatives in terms of regulations and technical norms.	Medium	Ensure adequate time for planning, design, testing, retesting, documentation and feedback on the systems and standards to be proposed. Evaluate current best circular economy and industry 4.0 regulations and technical norms.
14.2 Prepare booklets, infographics, documents and technical notes for dissemination in activities 14.3 and 14.4				
14.3 Disseminate best data protection practices to companies, including the booklet on Law No. 13.709 / 2018 - General Law for the Protection of Personal Data				
14.4 Disseminate best practices in legislation and data protection from other countries to companies				
14.5 Elaborate and disseminate internally the proposed technical norms for architecture, interoperability, integration of information technologies, communication and promotion of circular economy and industry 4.0 policies, based on the experiences of the demonstration projects in activities 9, 10 and 11				

Source: the author.

8.

Technology Action Plan **for Precision Agriculture**



8. TECHNOLOGY ACTION PLAN FOR PRECISION AGRICULTURE

8.1. Definition of technology

The definition of precision agriculture (PA) varies in the literature, but according to the Brazilian Commission for Precision Agriculture (CBAP), PA can be defined as a set of applied tools and technologies for an agricultural management system based on the spatial and temporal variability of the productive unit, aimed at increasing economic returns and reducing environmental impacts (BRASIL, 2014, p. 6).

The term was adopted approximately 25 years ago, but the facts and findings behind it are much older. Since agriculture began, there have always been reasons to care for crops in different ways in fields, orchards and gardens due to differences in planted areas (MOLIN; AMARAL; COLAÇO, 2015). However, with the expansion of agriculture through mechanization, which allowed for much greater areas to be cultivated, this was relegated to secondary importance, and large areas came be managed as though they were homogeneous. However, in view of the fact that there is spatial and temporal variability in the production unit, and that proper management can yield better results (LEONARD, 2015), the current practice of PA emerged with a new approach to agriculture (MOLIN; AMARAL; COLAÇO, 2015). The application of PA took off in the 1980s with the development of microcomputers, sensors and software in the United States and Europe, delivering improved results for producers (Ibidem).

Previously understood as a set of tools for crop management, PA has come to be seen as an agricultural production management system that brings together tools and technologies, from different areas of knowledge, to optimize and improve crop management. The technologies employed range from agricultural instruments to the development and use of models and management systems, including process automation, among others.

This management system is a successful example of applying automation to make production systems more efficient in rural areas (EMBRAPA, 2016). In addition, it plays an important role in the sustainability of agricultural systems as it seeks to optimize the use of resources. In conjunction with soil conservation practices and integrated pest management (IPM), it can contribute to increasing food production and mitigating climate change. Moreover, it is an opportunity to mitigate emissions by reducing the amounts of fertilizers, inputs and pesticides in agriculture. In economic terms, PA offers an increase in the productivity and profitability of agricultural crops, as well as a potential reduction in food prices due to increased supply.

8.2 Scope and goals

Sustainable agriculture with improved productivity and environmental conservation is already a reality on a number of farms, and these practices should continue to be improved and diffused. Best farming practices and modern technology are already a part of the daily lives of farmers in Brazil. PA is one of the most promising recent advances in agricultural production, as it is a management strategy that collects, processes and analyzes temporal, individual and spatial data, and combines this data with other data to support management decisions based on estimated variability in order to improve resource use, productivity, quality, profitability and sustainability (ISPA, 2019).

The set of PA tools and technologies has evolved considerably in recent years. In this context, the TAP for precision agriculture is aimed at the development, innovation, diffusion, training and dissemination of PA in Brazil. The goal of the TAP is to foster, disseminate and train the Brazilian agricultural sector in PA by 2030.

The creation of a Network to promote the development, innovation and diffusion of PA is of fundamental importance in the TAP as it is central to the other proposed activities for the implementation of initiatives, as well as PA training and dissemination for different stakeholders. The objective of the Network is to propose, promote, support and monitor activities to make PA increasingly accessible to all farmers. The Network will be responsible for bringing together leading research institutions, companies and government agencies involved in PA to understand the needs of the different links in the chain, and propose and monitor actions and research in PA, precision forestry, agriculture 4.0, digital agriculture, agricultural automation and IoT. This involves implementing and monitoring activities to develop or improve PA equipment, machinery and practices. Another task of the Network is training and the dissemination of the knowledge generated by the TAP through partnerships with educational institutions and agencies that have direct contact with rural producers.

The TAP goals are closely aligned with the Precision Agriculture Strategic Agenda 2014-2030 presented in 2014 by the Ministry of Agriculture, Livestock and Supply (Mapa) (BRASIL, 2014). The strategic agenda is the result of efforts that began in mid-2013 with the participation of members of the Brazilian Commission on Precision Agriculture (CBAP)[9], in which a number of aspirations, intentions and actions to promote the growth and dissemination of PA in Brazil were raised and discussed. The document includes 51 actions for nine strategic areas, addressing all links in the chain, as well as the obstacles to the diffusion of PA in Brazil.

In the strategic area of RD&I, the expected result is the creation of a precision agriculture RD&I Network to foster continuous innovation in PA through the following actions: i) needs analysis of the different links in the chain; ii) creation of the CBAP RD&I Network; iii) strategies to obtain resources for RD&I; iv) ensuring that PA is on the National Scientific and Technological Development Fund (FNDCT) agenda, via Map; and v) securing budgetary resources from the Federal Government. Thus, the TAP for PA aims to potentialize the expected results of the agenda's strategic RD&I goals, as well as the actions "i", "ii" and "iii" through the TAP activities described.

Table 80 – TAP scope and goals

SCOPE	GOALS
Technological development, innovation, diffusion, training and dissemination to foster PA in Brazil.	Promote the development, innovation, diffusion, training and dissemination of PA in Brazil by 2030.

Source: the author.

[9] Currently, the Brazilian Commission for Precision and Digital Agriculture (CBAPD). Established by Mapa in 2019, it is an advisory body for promoting the development of precision and digital agriculture in Brazil. (BRASIL, 2019).

8.3. Actions and activities

Critical gaps and barriers and means to overcome them

In an earlier stage of the TNA_BRAZIL project, we identified 15 significant barriers to the development and diffusion of PA technology in Brazil. Among these barriers, we selected the critical ones that, if not overcome, would hinder the dissemination of the technology, taking into account the goal to implement the project by 2030.

We identified five critical barriers to the development, dissemination and management of PA. Three are technological barriers, one is an economic barrier, and one concerns dissemination. To overcome these barriers, we proposed three actions and nine activities (presented below).

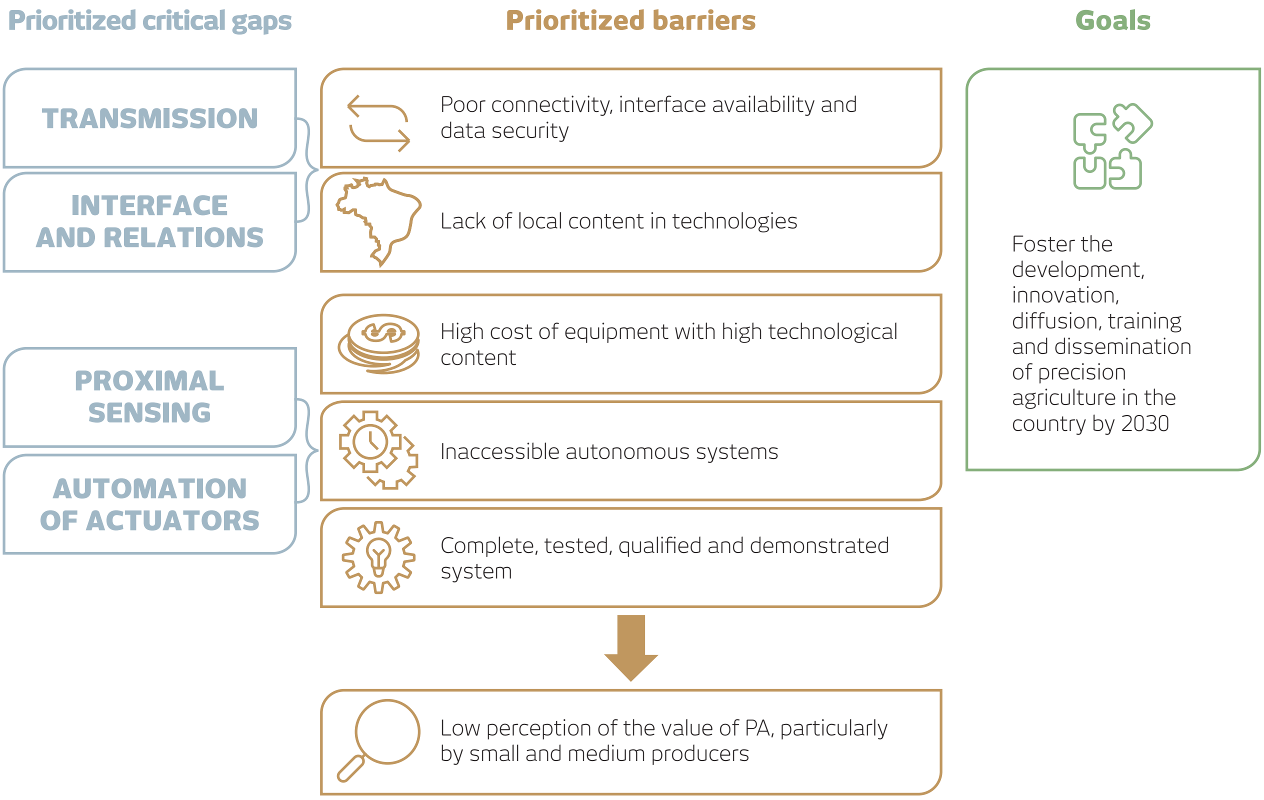


Figure 20 – Critical gaps and barriers and priority goals

Source: the author.

Actions and activities

Action 1 is critical to the success of the two subsequent actions. It defines the prerequisites, processes, targets, guidelines and arrangements for guiding technological development and diffusion, as well as the training and dissemination of PA techniques and practices. Partnerships are required to make the activities of the other actions viable as well.

The three TAP actions are defined as follows:

1. Creation of a Network to promote PA development, innovation and diffusion;
2. Foster the development, innovation and diffusion of PA technologies;
3. Training and dissemination for the adoption of PA techniques and practices.

Each action is composed of a group of activities for the step-by-step execution of the TAP.

Action 1 and related activities

Just as PA involves a wide range of tools and technologies, it also involves numerous stakeholders. Thus, it is essential to create a Network for the development, diffusion, innovation, training and dissemination of PA that reaches all stakeholders.

Action 1 is composed of four activities. This action mobilizes the largest number of stakeholders to ensure that their needs are represented. The Network seeks to coordinate current initiatives and establish criteria for future projects. The Network is also intended to coordinate and monitor the results of the other TAP actions.

Ideally, this action should be coordinated by CBAPD, an entity that currently promotes the development of precision and digital agriculture in the country (BRASIL, 2019). The creation, promotion and monitoring of the proposed actions for the development, innovation and dissemination of PA are aligned with the Commission's objectives, namely: i) disseminating and promoting the concept and techniques of precision and digital agriculture; ii) disseminating the importance of precision and digital agriculture for agricultural development and socio-environmental sustainability; iii) supporting programs for professional training and qualification and technical and scientific work related to precision and digital agriculture; iv) promoting knowledge and affordable technologies; v) supporting the creation and maintenance of a public domain database for activities related to the sector; vi) implementing and maintaining a virtual discussion forum on precision and digital agriculture; and vii) promoting coordination between public and private stakeholders to define priority actions for the sector.

The first activity involves establishing the Network's prerequisites and defining the mission, vision and values, performance model, strategic planning, communication plan, governance structure, institutional stakeholders and the Network permanent team. It should be noted that in sub-activities 1.2, 1.3 and 1.4, the final product should be a draft Ordinance to formally create the Network.

Sub-activity 1.4 is fundamental for the sustainability of the Network, as it defines the permanent team. To this end, there is a budget for personnel that covers the entire TAP implementation period. This team is also tasked with supporting the Network institutional stakeholders. Sub-activity 1.5 involves strategic planning for the Network as well as the elaboration of a TAP communication plan to subsidize, primarily, training and the dissemination of TAP activity results.

The second activity defines the Network's model and operating strategy. Initially, it will map the actions for PA and precision forestry currently underway. It also seeks to define the supply model for the technologies promoted in Action 2, as well as identify interested parties and the supply strategy through startups.

The Network permanent team (defined in sub-activity 1.4) will develop indicators for measuring and reporting the performance of TAP activities (activity 3), aimed at evaluating the performance of the Network and ensuring the quality of the actions. Finally, the fourth activity involves supporting and monitoring Actions 2 and 3 by the Network.

Table 81 – Action 1 and related activities

ACTION 1 – CREATION OF A NETWORK TO PROMOTE PA DEVELOPMENT, INNOVATION AND DIFFUSION	
Activity 1	Establish Network prerequisites and organization
Sub-activity 1.1	Define the Network's mission, vision and values
Sub-activity 1.2	Define the performance model with short-, medium- and long-term goals and the Network governance process
Sub-activity 1.3	Map stakeholders and leading national institutions for the Network
Sub-activity 1.4	Define the physical structure, performance model and institutional stakeholders and contract the Network permanent team
Sub-activity 1.5	Develop and apply the strategic planning and communication plan for Network operations
Activity 2	Define the Network performance model and strategy
Sub-activity 2.1	Map and correlate actions and research on PA, precision forestry, agriculture 4.0, digital agriculture, agricultural automation and IoT
Sub-activity 2.2	Define the supply model for the PA technologies promoted in activities 7 and 8
Sub-activity 2.3	Identify stakeholders and technology supply strategy through startups
Activity 3	Define indicators for measuring and reporting Network performance
Sub-activity 3.1	Define action plans, indicators, targets and correction plans to assess and report Network performance
Sub-activity 3.2	Evaluation and validation of sub-activity 3.1 by specialized consultants
Activity 4	Promote and monitor Network technology development and training actions
Sub-activity 4.1	Map financing sources and develop Terms of Reference for carrying out PA studies, research, demonstration projects and training
Sub-activity 4.2	Identify and establish partnerships for Network development, dissemination and training
Sub-activity 4.3	Manage and systematize the knowledge generated by the Network and monitor and disseminate the results of activities 6, 7, 8 and 9
Sub-activity 4.4	Systematize the results of Network activities in publications and content for dissemination

Source: the author.

Action 2 and related activities

Action 2 includes four activities with sub-activities to foster PA technology development and innovation. Activity 5 involves identifying the needs of the different links in the chain and niches with the greatest potential for PA technological development in Brazil.

It should be noted that the needs analysis, especially with respect to cloud computing, IoT and software packages to do this data processing, is a critical activity that should consider the results of the TAP actions for satellite monitoring. This is because there is synergy between this activity and the development of a high-resolution monitoring and territorial intelligence system (actions that are also part of this TAP). For this reason, initiatives should ideally explore synergies to maximize the chances of attaining the desired results with regard to the development, innovation and diffusion of PA.

Activities 6 and 7 share a common objective: equipment innovation and development in selected PA niches. The two activities have similar sub-activities, with parallel schedules that occur simultaneously following activity 5. These are applied RD&I activities and involve the execution of projects for: i) development and/or diffusion of AP equipment for small and medium producers; and ii) improving the automation of AP machinery and equipment.

The Terms of Reference, public notices or tenders for contracting these activities should include the following criteria as mandatory requirements in proposals: potential for mitigating GHG emissions; technical-economic feasibility study; business model for the solution; technical capacity and eligibility of the participating company; acceptance of publication of project results; concept replicability; preparation of material for training courses; and development of technical norms for communication and security.

Activity 8 is aimed at standardizing communication between machinery and equipment made by different manufacturers to facilitate interoperability, automation and IoT in PA. This requires an interface standard for connecting machines and equipment, independent of the generation, model or brand. This involves creating communication protocols and standardizing connectors, among other initiatives.

Table 82 – Action 2 and related activities

ACTION 2 – PROMOTION OF DEVELOPMENT, INNOVATION AND DIFFUSION OF PA TECHNOLOGIES	
Activity 5	Needs analysis of the different links in the PA chain and identification of niches with the greatest potential for PA technological development in Brazil
Sub-activity 5.1	Needs analysis for automated equipment and data processing
Sub-activity 5.2	Identify technologies for improving sensors, actuators, interfaces, models, data processing and AP software
Sub-activity 5.3	Creation of an RD&I program for the technologies identified in sub-activity 6.2
Activity 6	Execution of projects for financing, aimed at the development and/or diffusion of AP equipment for small and medium producers
Sub-activity 6.1	Define scope and requirements for AP products and processes for small and medium producers
Sub-activity 6.2	Elaborate Terms of Reference, public notices or tenders to develop and test PA equipment
Sub-activity 6.3	Launch tender schedule
Sub-activity 6.4	Receipt and evaluation of proposals
Sub-activity 6.5	Selection and contracting of sub-projects
Sub-activity 6.6	Sub-project kick-off meeting and training for contracted stakeholders
Sub-activity 6.7	Execution of AP equipment testing projects (limit of ten sub-projects)
Sub-activity 6.8	Monitoring and assistance for contracted parties during the project execution period
Activity 7	Promote research, development and innovation to improve the automation of machinery and equipment
Sub-activity 7.1	Define scope of national hardware and software to meet the demands in activity 5
Sub-activity 7.2	Elaborate Terms of Reference, public notices or tenders to develop and test AP machinery and equipment automation
Sub-activity 7.3	Launch tender schedule
Sub-activity 7.4	Receipt and evaluation of proposals
Sub-activity 7.5	Selection and contracting of sub-projects
Sub-activity 7.6	Sub-project kick-off meeting and training for contracted stakeholders
Sub-activity 7.7	Execution of projects to test AP automation equipment (limit of three sub-projects)
Sub-activity 7.8	Monitoring and assistance for contracted parties during the project execution period
Activity 8	Standardization and dissemination of regulations and technical norms for communication and connectivity in PA
Sub-activity 8.1	Identify benchmarks and initiatives to disseminate the standardization of communication and connectivity for PA machinery and equipment
Sub-activity 8.2	Identify best practices for disseminating data protection in PA
Sub-activity 8.3	Develop guidelines for standardizing communication and connectivity for PA machinery and equipment
Sub-activity 8.4	Develop guidelines for the elaboration of PA machinery and equipment norms and techniques

Source: the author.

Action 3 and related activities

The success of the processes developed in Action 2 depends on training and dissemination campaigns for both public and private stakeholders (Action 3). Thus, activity 9, and the six related sub-activities, focus on PA training and dissemination.

Ideally, there should be two areas of dissemination, with the first focused on training the partner producers who will participate in the tests in the development stage (Action 2) and the second to demonstrate and disseminate the results to other producers. Among small and medium producers, the dissemination actions are just as important (if not more) as the technological development actions.

There are also distance learning courses planned for small and medium producers to demonstrate the benefits and value of PA. Finally, it is important to prepare specialized labor on the implementation of PA technologies through the dissemination of guidelines and awareness raising for the development of elective courses in PA technologies for higher education in Exact and Earth Sciences and Engineering.

Table 83 – Action 3 and related activities

ACTION 3 – TRAINING AND DISSEMINATION FOR THE DEVELOPMENT OF PA TECHNIQUES AND PRACTICES	
Activity 9	PA training and dissemination
Sub-activity 9.1	Identify and select distance education platforms for the provision of courses
Sub-activity 9.2	Prepare the online course material for "Precision Agriculture Techniques and Practices"
Sub-activity 9.3	Provide four distance learning courses with a workload of 40 hours each
Sub-activity 9.4	Demonstrations and dissemination of the results obtained in activities 6, 7 and 8
Sub-activity 9.5	Elaborate material on the TAP actions for the PA Network website
Sub-activity 9.6	Elaboration and dissemination of guidelines and awareness raising for the development of elective courses on PA technologies for higher education in Exact and Earth Sciences and Engineering

Source: the author.

8.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

For each of the three actions, we prospected different stakeholders (public and private sector, associations and representative entities, among others) who could collaborate in the implementation of the TAP to ensure its success.

Initially, we can highlight institutions that could coordinate the TAP. As mentioned above, the mission of the CBAPD has synergy with the objectives of the TAP actions, and the TAP would serve as an instrument to subsidize the Commission's activities. In view of its expertise in technology and the work of the PA network, the MCTI and Mapa could act in the coordination of Action 1 and the technical coordination of the development, research and innovation activities (MCTI) and PA dissemination and training activities (Mapa).

Other stakeholders with recognized expertise in technology and whose missions are aligned with the TAP goals can be highlighted: i) financing agents (National Bank for Economic and Social Development – BNDES; Financier of Studies and Projects – Finep; Brazilian Industrial Research and Innovation Company – Embrapii, and National Council for Scientific and Technological Development – CNPq); ii) potential technical partners (Embrapa; universities, leading research institutes and laboratories; PA service providers; Telecommunications Research and Development Center – CPqD; Economic Research Institute Foundation – Fipe; Census; and the National Rural Training Service – Senar); and iii) Sectoral Chambers for validating the results of activities and participation in training and dissemination activities (Brazilian Precision Agriculture Association – Asbraap; National Association of Motor Vehicle Manufacturers – Anfavea; Brazilian Machinery and Equipment Industry Association – Abimaq; Brazilian Agriculture and Livestock Confederation – CNA; PA equipment manufacturers and suppliers; universities and research institutes; PA service providers; Senar; Inova; Auspin; Cargill Foundation; Pulse; Cubo; industry associations; and other innovation agencies and hubs).

Table 84 – Main stakeholders to involve in implementing the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Mapa	Mapa is responsible for the management of public policies to promote agriculture and agribusiness and for the regulation and standardization of services in the sector. Under its management, it seeks to integrate the marketing, technological, scientific, environmental and organizational aspects of the productive sector, as well as the supply, storage and transportation of crops and the management of agribusiness economic and financial policy. It could act in the coordination of Action 1 and the technical coordination of Action 3.
MCTI	The MCTI is involved in the following areas: national telecommunications policy, scientific and technological research, information technology and automation, among others. It could act in the coordination of Action 1 and the technical coordination of Action 2.
Embrapa	Embrapa provides R&D and innovation solutions for the sustainability of agriculture for the benefit of Brazilian society. Furthermore, it is a company dedicated to agricultural research and has a number of PA projects. It would be an ideal technical partner for the activities of Actions 2 and 3.

continues

continuation

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
CBAPD	The CBAPD’s tasks include: i) disseminating and promoting the concept and techniques of precision and digital agriculture; ii) disseminating the importance of precision and digital agriculture for agricultural development and socio-environmental sustainability; iii) supporting programs for professional training and qualification and technical and scientific work related to precision and digital agriculture; iv) promoting knowledge and affordable technologies; v) supporting the creation and maintenance of a public domain database for activities related to the sector; vi) implementing and maintaining a virtual discussion forum on precision and digital agriculture; and vii) promoting coordination between public and private stakeholders to define priority actions in the sector. It would receive subsidies from TAP activities.
Asbraap	The mission of the Brazilian Precision Agriculture Association (Asbraap) is ”to contribute to scientific and technological development, innovation and dissemination of the use of PA practices, techniques and technologies, here understood as the broad set of tools and technologies applied to provide an agricultural management system based on the spatial and environmental variability of the production unit, aimed at increasing economic returns and reducing environment impacts. It aims to bring together people, organizations and companies dedicated to the topic, in its broad view, in order to promote and disseminate it among the most varied communities and groups” (ASBRAAP, [s.d.]). It could act in the Sectoral Chambers to validate the results of activities and participate in the training and dissemination activities.
Anfavea	Among the tasks of the National Association of Motor Vehicle Manufacturers (Anfavea) are: ”to study aspects of the industry and market for agricultural and road vehicles and machines, to coordinate and defend the collective interests of the associated companies, to participate, sponsor or support, on an institutional basis, events and exhibitions related to the industry and compile and disseminate sector performance data” (ANFAVEA, [sd]). It could act in the Sectoral Chambers to validate the results of activities and participate in the training and dissemination activities.
Abimaq	The mission of the Brazilian Machinery and Equipment Industry Association (Abimaq) is ”to act independently to promote the sustainable development of the sector through products, services and political-institutional actions” (ABIMAQ, [s.d.]). It could act in the Sectoral Chambers to validate the results of activities and participate in the training and dissemination activities.
CNA	Among other tasks, the Brazilian Agriculture and Livestock Confederation (CNA) ”is responsible for bringing together associations and political and rural leaders across the country. It also supports the development of new technologies that can assist the producer in planting and management and the creation of agro-industries aimed at increasing rural productivity” (CNA, [nd] a). It could act in the Sectoral Chambers to validate the results of activities and participate in the training and dissemination activities.
Industry and professional associations	They could act in the technical support activities in the Sectoral Chambers of specialists to support the results validation process, as well as in training and dissemination activities.
PA service providers	They could act in the Sectoral Chambers to validate the results of activities and participate in the training and dissemination activities. Furthermore, they are potential partners for carrying out the activities.
PA equipment manufacturers and suppliers	They could act in the Sectoral Chambers to validate the results of activities and participate in the training and dissemination activities.
Universities and research institutes	They could be responsible for technical support and training programs.

continues

continuation

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Senar	The mission of the National Rural Training Service (Senar) is to "provide professional education, technical assistance and social development activities, contributing to improving the development of sustainable production, competitiveness and social advances in the field. Among its actions, are: rural professional training, technical assistance and social development" (CNA, [sd] b). It could act in the Sectoral Chambers to validate the results of activities and participate in the training and dissemination activities. Furthermore, it is a potential partner for the implementation of Action 3.
Finep	The Financier of Studies and Projects promotes science, technology and innovation in companies, universities, technological institutes and other public and private institutions. It participates throughout the innovation chain, focusing on strategic, structural and impact actions for the sustainable development of Brazil. It could act as a financing agency for TAP activities.
BNDES	BNDES is the main Federal Government instrument for long-term financing and investments in all segments of the Brazilian economy. It could act as a financing agent for TAP activities.
CNPq	CNPq promotes and fosters scientific and technological development in Brazil and contributes to the formulation of national science and technology policies. It could support the promotion of TAP activities.
Embrapii	Embrapii supports institutions to carry out technological research development projects for innovation, in cooperation with companies in the industrial sector. It could act in activities to promote the TAP.
Inova	The mission of Inova is "to identify opportunities and promote activities that stimulate innovation and entrepreneurship, broadening the impacts of teaching, research and education for sustainable socioeconomic development" (INOVA, [s.d.]). It could act in the Sectoral Chambers to validate the results of activities and participate in the training and dissemination activities.
Auspin	The Auspin innovation center's mission is "to promote the use of scientific, technological and cultural knowledge produced at the University of São Paulo to foster the socioeconomic development of the state of São Paulo and the country" (AUSPIN, [s.d.]). It could act in the Sectoral Chambers to validate the results of activities and participate in the training and dissemination activities.
Cargill Foundation	The mission of the Cargill Foundation is to "promote healthy, safe, sustainable and affordable food, from the field to the consumer" (CARGILL, [s.d.]). It could act in the Sectoral Chambers to validate the results of activities and participate in the training and dissemination activities.
UFPR innovation agency	Among the objectives of the agency, the following stand out: "supporting the internal community in the requirements for knowledge protection; guiding the procedures, in conjunction with other administrative units, for technology transfer; defining training plans and events for entrepreneurship and projects for innovative business" (AGÊNCIA DE INOVAÇÃO UFPR, [s.d.]). It could provide technical and operational support.
Pulse	Pulse promotes links between startups, corporations, investors, entities and universities. It hosts and contributes to the growth of startups, working collaboratively with partners and players in industry and agribusiness. It could act in the Sectoral Chambers to validate the results of activities and participate in the training and dissemination activities.
Cubo	It could provide technical and operational support.
Innovation agencies and hubs	They could provide technical and operational support.
Universities and research centers	They are responsible for producing excellent technical and scientific knowledge in Brazil.
Fipe	The Economic Research Institute Foundation (Fipe) conducts field research and has the necessary expertise for data processing and preliminary analysis. It could act as a technical partner in the execution of activities.
Census	Census conducts field research and has the necessary expertise for data processing and preliminary analysis. It could act as a technical partner in the execution of activities.
CPqD	The Telecommunications Research and Development Center (CPqD) could be a partner in the execution of activity 8, as the company offers solutions in IoT; blockchain; smart connectivity; and artificial intelligence.

Source: the author.

Schedule of actions and activities

The time frame for implementing the TAP is eight and a half years, a time believed adequate and sufficient for the technical and financial preparation and implementation of the TAP activities.

The activities can be implemented concurrently, as well as most of activity 9. Sub-activity 1.5 extends over the entire schedule, as it requires continuous efforts to apply and monitor the strategic planning and communication plan.

Activity 9 is extremely important for the success of the TAP as it addresses the dissemination of PA technologies. Moreover, it is dependent on the results of Action 2, which is why it is carried out over the last nine semesters of the schedule.

Table 85 – TAP implementation schedule

Sub-activityS	IMPLEMENTATION SCHEDULE																	
	Ano 1		Ano 2		Ano 3		Ano 4		Ano 5		Ano 6		Ano 7		Ano 8		Ano 9	
	1 SMT	2 SMT	3 SMT	4 SMT	5 SMT	6 SMT	7 SMT	8 SMT	9 SMT	10 SMT	11 SMT	12 SMT	13 SMT	14 SMT	15 SMT	16 SMT	17 SMT	18 SMT
1.1	■																	
1.2	■																	
1.3	■																	
1.4	■																	
1.5	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
2.1		■																
2.2		■																
2.3		■																
3.1			■															
3.2			■															
4.1			■															
4.2				■														
4.3					■	■	■	■	■	■	■	■	■	■				
4.4															■	■	■	
5.1					■													
5.2						■												
5.3							■											
6.1								■										
6.2								■										
6.3								■										
6.4								■										
6.5								■										
6.6								■										
6.7									■	■	■	■						
6.8									■	■	■	■						

continues

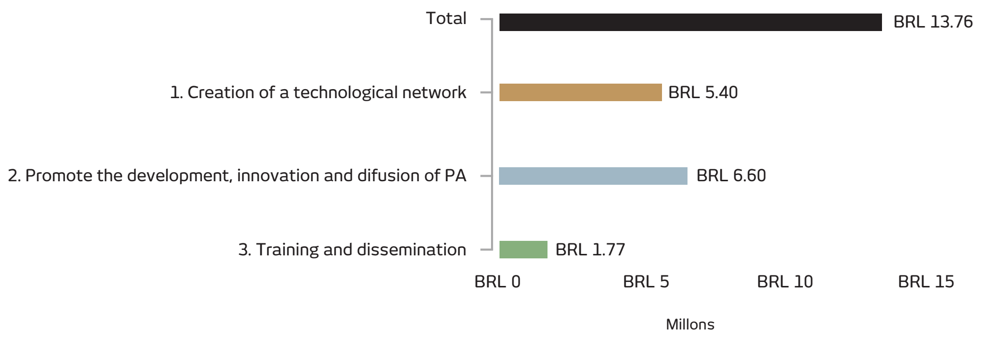
continuation

Sub-activityS	IMPLEMENTATION SCHEDULE																	
	Ano 1		Ano 2		Ano 3		Ano 4		Ano 5		Ano 6		Ano 7		Ano 8		Ano 9	
	1 SMT	2 SMT	3 SMT	4 SMT	5 SMT	6 SMT	7 SMT	8 SMT	9 SMT	10 SMT	11 SMT	12 SMT	13 SMT	14 SMT	15 SMT	16 SMT	17 SMT	18 SMT
7.1								■										
7.2								■										
7.3								■										
7.4								■										
7.5								■										
7.6								■										
7.7									■	■	■	■						
7.8									■	■	■	■						
8.1													■					
8.2													■					
8.3														■				
8.4														■				
9.1									■		■	■	■	■	■	■		
9.2									■		■	■	■	■	■	■		
9.3										■		■		■		■		
9.4													■	■	■	■	■	
9.5													■	■	■	■	■	
9.6															■	■	■	

Source: the author.

8.5. TAP implementation costs and financing options

The total cost of the TAP was estimated at approximately BRL 13.8 million. Action 2, which involves the development of PA technologies, is the most significant in terms of costs, followed by the activity for the creation of the Network, which has high costs since it occurs over the TAP schedule.



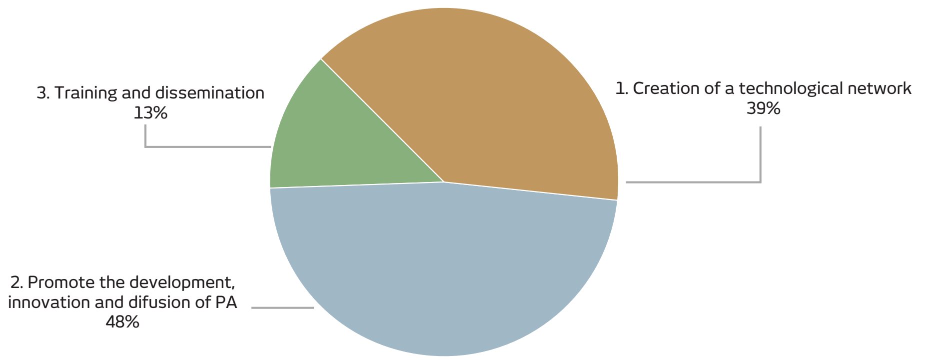


Figure 21 – Total cost per action, in millions of BRL and as a percentage, for the TAP for precision agriculture

Source: the author.

With respect to potential sources of financing for the activities, and with a view to financial results and a focus on research and development, we determined the typical means of financing would be non-repayable loans and technical assistance. Financing is accessible for state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives. Activities involving the financing of demonstration projects (6 and 7) would be financed by repayable loans. This financing source is applicable to all the stakeholders mentioned above.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication “Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project” and in the “Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project” (BRASIL, 2021a; 2021b).

8.6. Risk and contingency plan

In addition to the cost estimates, we analyzed the potential risks involved to implement the TAP activities. The following risk categories were considered: political, institutional, organizational, technical and cost risks.

They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs).

Finally, contingency actions were proposed to mitigate these risks.

The highest risks are associated with activities 6 and 7 (development and dissemination of PA technology), which involve large budgets and numerous stakeholders. The risks include difficulties in accessing producers, problems with equipment testing and inadequate process monitoring. There is also the risk of stakeholder competition to prioritize certain aspects of the project that could undermine the progress of the TAP. In addition, there is the risk of inadequate definition of the scope and minimum requirements for the tender for development projects. There is also the risk of not securing financial resources for the projects and contracted parties failing to fulfill their obligations.

Table 86 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1 Define the Network's mission, vision and values 1.2 Define the performance model, with short-, medium- and long-term goals, and the Network governance process 1.3 Map Network stakeholders and leading national institutions 1.4 Define the physical structure, performance model, institutional stakeholders and contract the Network permanent team 1.5 Develop and apply the Network strategic planning and communication plan	Institutional risk and technical risk	Potential different stakeholder interests and expectations for the project could compromise participation of institutions. Lack of technical coordination for activities and difficulty contracting qualified labor. Poor application of strategic planning and communication plan across TAP actions.	Medium	Employ management and development methods for the Network to balance goals with the personal expectations of each representative to ensure a balance of power over the project life cycle. Contract a team (with permanent technical coordination) for the Network that has extensive expertise in creating Networks and/or PA. Contract a professional for the TAP implementation period to monitor the application of the Network strategic planning and communication plan.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
2.1 Map and correlate actions and research on PA, precision forestry, agriculture 4.0, digital agriculture, agricultural automation and IoT	Technical risk and organizational risk	Lack of stakeholders. Difficulty defining the validation model with stakeholders. Lack of technical coordination and stakeholder engagement.	Low	Encourage the participation of Network institutional partners through periodic meetings. Validate the supply model in a workshop and apply the multi-criteria methodology. Look for recognized partners who already have a relationship with startups and ensure support throughout the development process. Ensure technical coordination of activities.
2.2 Definition of the supply model for PA technologies developed in activities 7 and 8				
2.3 Identify stakeholders and supply strategy through startups				
3.1 Define action plans, indicators, targets and correction plans to assess and report the performance of the Network	Technical risk	Difficulty defining adequate indicators and failure to achieve the goals.	Low	Contract qualified and experienced professionals to develop a robust plan for activities and define metrics.
3.2 Evaluation and validation of sub-activity 3.1 by specialized consultants				
4.1 Map financing sources and elaborate Terms of Reference for carrying out studies, research, demonstration projects and training on PA	Technical risk, organizational risk and political risk	Difficulty identifying partners interested in developing and disseminating PA technologies and practices and training. Lack of team qualifications and/or commitment to the project. Potential political interests and disputes over financial resources that undermine the execution of specific TAP activities. Inability to attract stakeholders to participate in the development of technological and training solutions that meet the prerequisites for contracting and scope. Lack of coordination in the systematization of information.	Medium	Train and coordinate the team. Elaborate material in conjunction with communication consultants that demonstrates the potential to multiply the knowledge generated by the Network. Support and monitor partners throughout the project life cycle. Ensure flexibility in management so that the project becomes a platform with different goals and objectives. Ensure Network manager representation and authority.
4.2 Identify and establish partners for Network development, dissemination and training				
4.3 Manage and systematize the knowledge generated by the Network for the monitoring and dissemination of the results of activities 6, 7, 8 and 9				
4.4 Systematize the results of Network activities in publications and material for dissemination				

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
5.1 Needs analysis for automated equipment and data processing	Technical risk	Failure to identify the real needs due to incorrect data collection and processing. Errors in the elaboration of the questionnaire. Lack of qualified labor and technical coordination. Unable to mobilize stakeholders to carry out actions for the development and diffusion of PA technologies.	Low	Contract a professional with experience to prepare the questionnaire for the needs analysis. Use effective technologies and tools by contracting research institutes, and validation by leading laboratories and PA associations. Validation by industry experts in a workshop, as well as dissemination of the RD&I program by science and technology stakeholders.
5.2 Identify technologies for improving sensors, actuators, interfaces, models, data processing and PA software				
5.3 RD&I for the technologies identified in sub-activity 6.2				
6.1 Define scope and requirements for PA products and processes for small and medium producers	Technical risk, political risk, cost risk and institutional risk	Difficulty accessing producers, failures in equipment testing and inadequate monitoring of processes. Potential stakeholder competition to prioritize certain aspects that could undermine the progress of the project. Poor definition of scope and minimum tender requirements. Risk of not securing financial resources for the projects. Risk of contracted parties not fulfilling their obligations for a variety of reasons.	High	Establish partnerships with institutions that have links to small and medium producers. Establish partnerships with producer associations and important PA representatives. Cooperate with the main national and international technology promotion agencies. Contract a consulting team to evaluate and validate the tenders. Ensure clear Network performance and highlight the TAP benefits to ensure the necessary financial resources. Assess the skills of contracted individuals beforehand and check their references to ensure success, and clearly define their roles.
6.2 Elaborate Terms of Reference, public notices or tenders to develop and test PA equipment				
6.3 Launch tender schedule				
6.4 Receipt and evaluation of proposals				
6.5 Selection and contracting of sub-projects				
6.6 Sub-project kick-off meeting and training with contracted stakeholders				
6.7 Execution of PA equipment testing projects (limit of ten sub-projects)				
6.8 Monitoring and assistance for contracted parties during the project execution period				

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
7.1 Define scope of national hardware and software to meet the requirements identified in activity 5	Technical risk, political risk, cost risk and institutional risk	Difficulty accessing producers, failures in equipment testing and inadequate monitoring of processes. Potential stakeholder competition to prioritize certain aspects that could undermine the progress of the project. Poor definition of scope and minimum tender requirements. Risk of not securing financial resources for the projects. Risk of contracted parties not fulfilling their obligations for a variety of reasons.	High	Establish partnerships with producer associations and important PA representatives. Cooperate with the main national and international technology promotion agencies. Contract a consulting team to evaluate and validate the tenders. Ensure clear Network performance and highlight the TAP benefits to ensure the necessary financial resources. Assess the skills of contracted individuals beforehand and check their references to ensure success, and clearly define their roles.
7.2 Elaborate Terms of Reference, public notices or tenders to develop and test PA machinery and equipment automation				
7.3 Launch tender schedule				
7.4 Receipt and evaluation of proposals				
7.5 Selection and contracting of sub-projects				
7.6 Sub-project kick-off meeting and training with contracted stakeholders				
7.7 Execution of projects to test PA equipment automation (limit of three sub-projects)				
7.8 Monitoring and assistance for contracted parties during the project execution period				

continues

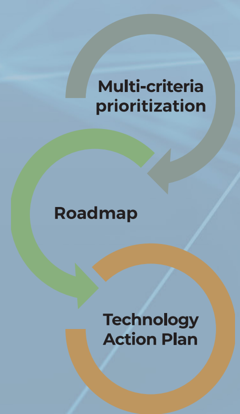
continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
8.1 Identify benchmark and initiatives to disseminate the standardization of communication and connectivity for PA machinery and equipment	Technical risk and institutional risk	Potential disagreements between AP machinery and equipment representatives over the standards for connectivity and communication. Lack of stakeholder interest.	Low	Validate the results of activities in a workshop.
8.2 Identify best practices for disseminating data protection in PA				
8.3 Develop guidelines for standardizing communication and connectivity for PA machinery and equipment				
8.4 Develop guidelines for the development of PA machinery and equipment technical norms and techniques				
9.1 Identify and select distance learning platforms for the provision of courses	Technical risk and organizational risk	Potential cultural resistance among producers to adopt PA and employ the techniques and equipment developed in the project. Risks related to the quality of the courses and the content for dissemination.	Low	Contract qualified professionals. Carry out quality checks in each step and, when necessary, implement changes immediately. Use evaluation forms in distance education courses.
9.2 Prepare the distance education course material for "Precision Agriculture Techniques and Practices"				
9.3 Provide four distance learning courses, with a workload of 40 hours each				
9.4 Demonstration and dissemination of the results obtained in activities 6, 7 and 8				
9.5 Develop and provide content from the actions on the Precision Agriculture Network website				
9.6 Elaboration, dissemination of guidelines and awareness raising for the development of elective courses on PA technologies for higher education in Exact and Earth Sciences and Engineering	Institutional risk and organizational risk	Potential lack of engagement from teachers not used to digital teaching resources. Difficulty in understanding the educational goals. Difficulty contracting specialized labor.	Low	Train teachers in the project results. Contract specialized labor to formulate higher education proposals. Carry out engagement activities at universities, based on the communication plan for the training and dissemination action.

Source: the author.

9.

Technology Action Plan **for Genetic Improvement in Beef Cattle**



9. TECHNOLOGY ACTION PLAN FOR GENETIC IMPROVEMENT IN BEEF CATTLE

9.1. Definition of technology

Genetic improvement (GI) allows for the modification of the genetic composition of herds over generations, aimed at aligning herd characteristics with the production environment, performance expectations, market or production environment demands and market expectations. In Brazil, it is already widely employed and contributes to the development of the main animal production chains, including poultry, swine and beef and dairy. Large poultry and pork production companies have their own breeding programs to ensure their products satisfy consumer demands. In the case of beef and dairy cattle, there are independent genetic improvement programs, or programs linked to breeder associations, to help breeders and commercial producers use better quality genetic material in production processes.

Beef cattle is one of the main agricultural activities in Brazil, both in terms of revenues and environmental impacts. In 2019, the gross production value (GPV) of the beef cattle production chain was BRL 88.5 billion and represented approximately 14% of the total agricultural production value (BRASIL, 2019a). Enteric fermentation in beef and dairy cattle was responsible for 67% of Brazil's methane emissions in 2010 (BRASIL, 2016b). Thus, the application of technologies with the potential to increase productivity, profitability and mitigate GHG emissions in beef production - as is the case with genetic improvement - should be considered a priority in RD&I programs.

The genetic composition of herds can be modified through selection (selection of breeding individuals) and mating (strategies for pairing individuals). Genetic improvement is efficient for modifying the averages of economically important characteristics in a positive manner, as long as they are measurable and there is genetic variability. Thus, it is possible to improve characteristics related to reproduction, growth, feeding efficiency and adaptation to climate and parasites.

The main users of improved genetic material are commercial producers who raise animals for slaughter. The biggest beneficiaries of this, however, are the final consumers who have access to high quality food, produced in a sustainable manner. In genetic improvement processes, the aim is to identify, select and breed animals that grow faster, use food more efficiently, reproduce earlier and go to slaughter earlier. This allows for a reduction in the amount of natural resources used per unit of product (kilogram of meat), a smaller environmental footprint for beef production due to improved zootechnical indexes (reproduction, growth, feed efficiency) and greater competitiveness in the sector.

Among the benefits of genetic improvement, we can cite improved resilience to climate change and reductions in emissions. In the latter case, enteric fermentation in cattle is considered the main source of GHG emissions in the beef production chain. In traditional beef cattle production systems, most GHG emissions occur in the gestation and fattening phases. In intensive livestock systems (with a younger slaughter age), the gestation phase becomes the main source of GHG emissions (FLORINDO et al., 2017). Thus, the use of tools like genetic improvement to improve reproduction and growth characteristics will lessen the environmental impacts of the beef production chain (ABY et al., 2013). Genetic improvement can also contribute directly to reducing the environmental impacts of beef production, through selection, by reducing methane emissions (PINARES-PATINO et al., 2013), or indirectly, through selection to improve feed efficiency, since more efficient animals produce less CH_4 per kilo of body weight than less efficient animals (NKRUMAH et al., 2006).

9.2 Scope and goals

Genetic improvement is a technology with great potential for improving environmental, production, social and economic impacts in cattle farming in Brazil. This technology is already contributing to the improvement of growth and reproductive efficiency characteristics of animals, thanks to research, large-scale phenotyping and routine genetic assessments in genetic improvement programs (ABCZ, 2020).

Currently, with the development of equipment that can measure individual food consumption and even GHG production and emissions, it is now possible to conduct research to quantify the genetic differences between animals to determine characteristics related to feed efficiency. However, we still need to develop large-scale phenotyping of these characteristics so that programs can carry out genetic assessments and identify the most efficient animals.

The identification of genetically superior animals involves a number of steps and procedures that are usually carried out on farms that specialize in the selection and sale of superior genetic material (bulls, cows, semen and embryos). Genealogical control, individual identification and investments in equipment and specialized labor for phenotyping are examples of specific procedures that are carried out on selection farms and which increase production costs. These costs are recovered by selling value-added products (genetic material) to commercial farms.

The genetic material developed on selection farms is one of the essential inputs for raising beef cattle on commercial farms (ALVES et al., 1995). Like other companies, commercial farms need to have control over their production processes and costs to ensure sustainability (EL-MEMARI NETO, 2019). Some of them turn to specialized business management companies for support. These companies provide services for the economic, production and strategic planning of livestock production and assist farmers in making decisions based on economic data. These are commercial farms with large-scale meat production capacities that are specialized in transforming production inputs (genetics, nutrition, health, management, human resources etc.) into meat in a sustainable manner. Regardless of the importance of beef for human nutrition (PEREIRA; VICENTE, 2013) and the generation of income and social well-being (IBGE, 2017), this product is mainly commercialized as a commodity, without much added value. For this reason, the processes on a commercial farm are aimed at reducing costs, and are not necessarily the same as those used on genetic selection farms. Genealogical control, individual identification and investments in phenotyping characteristics are less important on commercial farms than on selection farms. Thus, whenever possible, commercial farms avoid these procedures.

In short, selection farms produce animals with superior genetic potential, and their production costs are not completely aligned with the costs of producing animals for slaughter on commercial farms. Commercial farms (the majority of Brazilian farms) are the main users of the genetic material developed on specialized selection farms, and should be seen as an important source of zootechnical and economic performance data for guiding genetic selection programs. Unfortunately, there is still a gap between these two groups of farms. This means there is the possibility that genetic improvement programs are not always developing the most suitable genetic material for commercial farms and, conversely, that data from commercial farms does not reach genetic improvement programs to assist in the selection process.

Bringing together the zootechnical and economic performance data from commercial farms and the zootechnical performance data and genetic parameters from genetic selection farms would allow genetic selection to better achieve its objective. The definition of this objective can be considered the singular most important stage of a genetic improvement program as it guides the selection of animals on farms according to the demands of commercial farms. With this objective well defined, the producers of genetic material (selection farms) understand the needs of their clients (commercial farms), and the client can be assured the genetic material supplier is offering a product that meets his needs, benefiting all stakeholders involved in the beef production chain. However, bringing together the data from genetic selection farms and the data from commercial farms to determine selection objectives requires a great deal of effort. This is the scope of the TAP for genetic improvement of beef cattle.

Table 87 – TAP scope and goals

SCOPE	GOALS
Integration of economic, zootechnical, genealogical and genotype data to improve genetic selection in beef cattle.	Develop a platform for the integration, dissemination, training and analysis of economic, zootechnical, genealogical and genotype data on beef cattle by 2030.

Source: the author.

Beef production is a dynamic activity, where the data generated on the farm (mainly related to the production process) and off the farm (consumer market) needs to be compiled and analyzed quickly and efficiently to provide information that can assist producers in their decision making. To this end, we identified the actions and activities necessary to achieve the proposed scope and goals of the TAP. These actions and activities are aimed at developing a platform for integrating data from selection farms and commercial farms by 2030 to facilitate the transformation of routinely generated data into strategic information for decision-making on selection and commercial farms.

9.3. Actions and activities

Critical gaps and barriers and means to overcome them

In the analysis of the genetic improvement technology value chain for beef production, we identified seven critical gaps (selection objectives, phenotyping, genotyping, genetic evaluation, selection/pairing, reproduction and commercialization) as well as eight barriers. In the prioritization stage, we considered the definition of selection objectives to be the most important gap, as it is at the beginning of the value chain. Knowledge of the selection objectives is fundamental for defining and executing the activities in a genetic improvement program. Following this, we identified the three most critical barriers to the diffusion of the technology. Among the three prioritized barriers, one is physical (differences between production systems in Brazil), one is related to dissemination and training (ignorance of the economic importance of characteristics) and the last is technological (lack of integration and agility among stakeholders involved in genetic improvement programs). To overcome these barriers, we propose the creation of a platform for the integration, dissemination, training and analysis of economic, zootechnical, genealogical and genotype data on beef cattle by 2030.

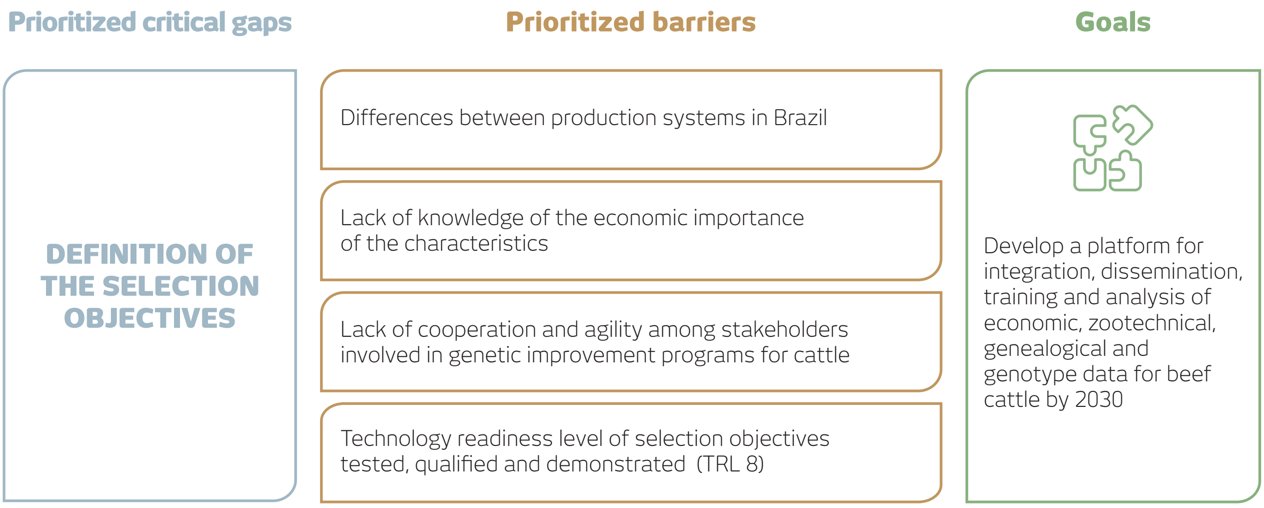


Figure 22 – Critical gaps and barriers and priority goals

Source: the author.

Actions and activities

The first two actions involve an analysis beef production and the perceptions of suppliers and users of bovine genetics. Action 3 is aimed at improving knowledge on the genetic resources available for beef production. Action 4 seeks to demonstrate the potential for economic benefits from genetic improvement in beef cattle. This action depends on the results of the previous actions. Action 5 is necessary to ensure the TAP benefits continue contributing to the development of the beef production chain even after the completion of all the planned actions. The development of the platform for data integration and analysis and reporting will allow the economic and zootechnical performance data from selection and commercial farms to be routinely and continuously analyzed, so that information is available to breeders and meat producers. Finally, Action 6 involves the dissemination of the results obtained in the previous stages, as well as training platform users. Each action is composed of a set of activities and sub-activities for the step-by-step execution of the TAP.

Action 1 and related activities

Action 1 consists of a production and economic analysis of beef production and includes three activities. Sub-activity 1.1 involves an analysis of current best indicators for production (animal performance, stocking rate etc.), economic performance (labor costs, production inputs, taxes, equipment and infrastructure maintenance, investments etc.) physical aspects (production area, herd size, production etc.), climatic conditions (precipitation, temperature, humidity, soil type, municipality, state, region etc.) and the production profile (technologies used etc.) of 300 commercial farms in the main beef producing regions of Brazil. This data will be extracted directly from the databases of management companies that, potentially, will also participate in the implementation of the TAP. As the data comes from different sources (different companies), there is a need to develop and standardize a methodology for calculating additional indicators (the indicators obtained in sub-activity 1.1) with the ability to characterize and discriminate production systems (sub-activity 1.2). In addition, a standardized data analysis methodology and multivariate analysis techniques should be developed for grouping the farms. These groups of farms (production systems) should be characterized based on the averages of their indicators.

Sub-activity 1.3 is complementary to the previous activities and consists of quantifying the contributions (absolute and relative) of each production system (groups of farms identified in sub-activity 1.2) to total beef production in Brazil.

Table 88 – Action 1 and related activities

ACTION 1 – PRODUCTION AND ECONOMIC CHARACTERIZATION OF BEEF PRODUCTION	
Sub-activity 1.1	Analysis of current best production, economic, physical and climatic indicators and production profile of 300 farms in the main beef producing regions of Brazil
Sub-activity 1.2	Develop and standardize a methodology for calculating and analyzing data from additional indicators with the ability to characterize and discriminate production systems
Sub-activity 1.3	Quantify the contribution (absolute and relative) of each production system (groups of farms identified in sub-activity 1.1) to total beef production in Brazil

Source: the author.

Action 2 and related activities

Action 2 is aimed at characterizing the supply and demand for genetic material for beef production. Sub-activity 2.1 consists of analyzing executed genetic improvement projects and their results, as well as defining two samples of farms to apply research questionnaires. The first sample should consist of 150 commercial farms, and the second sample of 100 selection farms. It is important to select commercial farms that represent the main production systems identified in the previous action, and genetic selection farms that provide genetic material for the group of farms in the previous sample.

Sub-activity 2.2 involves characterizing the strategies used by beef producers to acquire genetic material through the elaboration and application of questionnaires. The relative contributions of artificial insemination, fixed-time artificial insemination and natural breeding should also be quantified. It should also identify the criteria used for the acquisition of genetic material (semen, bulls, embryos or replacement females). The analysis should characterize the needs and expectations of meat producers in relation to the appropriate genetic material for their production system, as well as in relation to suppliers of genetic material. In addition, the analysis should identify expectations concerning the contribution of genetic improvement in the beef cattle production chain. The questionnaires will be applied with the assistance of consultants from the management companies involved.

Sub-activity 2.3 is aimed at characterizing the strategies used by suppliers of genetic material in their production systems. Questionnaires for data collection will also be applied with the support of field technicians from genetic improvement programs. This involves an analysis of the indicators for determining the genetic merit of animals, selection criteria, selection intensity, generation intervals and the flow of genetic material in selection farms. It is also aimed at characterizing the expectations of genetic material suppliers with respect to the use of their genetic material. In addition, it will be necessary to compile and analyze a database with records of genealogy, birth and genetic values of animals on 100 farms that produce and supply genetic material. This should be carried out with the support of animal genetic improvement programs.

Finally, sub-activity 2.4 involves the analysis and interpretation of the results of sub-activities 2.2 and 2.3. The product of this activity is a report on opportunities in genetic improvement.

Table 89 – Action 2 and related activities

ACTION 2 – CHARACTERIZATION OF SUPPLY AND DEMAND FOR GENETIC MATERIAL FOR BEEF PRODUCTION	
Sub-activity 2.1	Analysis of available data and identification of locations and samples to characterize strategies of meat producers and genetic material suppliers
Sub-activity 2.2	Characterize strategies used by meat producers to acquire genetic material (development and application of research on farms)
Sub-activity 2.3	Characterize strategies used by genetic material suppliers in their production systems, and compile and analyze a database with data on genealogy, birth and genetic values of animals (research on farms that produce and supply genetic material)
Sub-activity 2.4	Analysis and interpretation of the results of sub-activities 2.2 and 2.3 to generate a report on opportunities in genetic improvement

Source: the author.

Action 3 and related activities

Action 3 involves the design and execution of field experiments to characterize the genetic resources available for beef production in three activities.

Sub-activity 3.1 seeks to identify new selection criteria for the main breeds and beef production systems. Initially, this involves a systematic review of projects executed (or in progress), as well as their results, regarding selection criteria and, in a complementary manner, the compilation of databases with important new characteristics (growth, feed efficiency, resistance to parasites, adaptation, precocity and fertility, meat quality etc.), in addition to estimating genetic parameters for genetic improvement programs.

Sub-activity 3.2 involves characterizing genetic variability in the main beef cattle breeds, as well as compiling databases (genotypes and genomes) and characterizing genomes of the main beef cattle breeds. Finally, it seeks to develop strategies to mitigate the reduction of genetic variability.

Finally, sub-activity 3.3 involves developing and validating routines and software for data collection and storage, carrying out statistical analysis on phenotypes (sub-activity 3.1) and genotypes (sub-activity 3.2), and identifying regions of the genome associated with the characteristics of interest.

Table 90 – Action 3 and related activities

ACTION 3 – CHARACTERIZATION OF GENETIC RESOURCES AVAILABLE FOR BEEF PRODUCTION	
Sub-activity 3.1	Identification of new selection criteria for the main breeds of beef cattle and construction of a database with important new characteristics and estimation of genetic parameters for the design of genetic improvement programs
Sub-activity 3.2	Characterization of genetic variability in the main breeds of beef cattle, as well as the construction of databases (genotypes and genomes) and genome characterization of the main breeds of beef cattle
Sub-activity 3.3	Development of routines and software for data collection and storage for statistical analysis on phenotypes (sub-activity 3.1) and genotypes (sub-activity 3.2), and to identify regions with the genome associated with characteristics of interest

Source: the author.

Action 4 and related activities

One of the most efficient ways to promote the commercial adoption of a technology is by demonstrating its benefits, which can be economic, environmental, production or social benefits. Action 4 consists of two activities aimed at demonstrating the economic benefits of genetic improvement for commercial producers. This requires the development and implementation of a methodology for calculating the economic values of important characteristics (sub-activity 4.1), taking into account the characteristics of the different production systems identified in Action 1, the needs of users identified in Action 2 and the genetic parameters obtained in Action 3.

Sub-activity 4.2 involves developing theoretical models, taking into account genetic parameters (sub-activity 3.1), economic values of desired characteristics (sub-activity 4.1) and real models (evaluation under real production conditions) to quantify the economic, environmental and production benefits of using superior genetic material (selection), as well as from different mating systems (crossbreeding). The real data will be extracted from the databases of commercial farms provided by management companies, which are also potential technical partners for the execution of the activity. This involves defining sampling and grouping strategies for the farms, with the expectation of compiling a database with data from at least 50 farms.

Table 91 – Action 4 and related activities

ACTION 4 – QUANTIFICATION OF THE ECONOMIC BENEFITS OF GENETIC IMPROVEMENT	
Sub-activity 4.1	Development and implementation of a methodology for calculating the economic values of the characteristics mapped in previous activities
Sub-activity 4.2	Quantification of the economic, environmental and production benefits of using superior genetic material (selection), as well as different mating systems (crossbreeding) on 50 farms

Source: the author.

Action 5 and related activities

Currently, the genetic selectors are faced with the problem of agility for analyzing data generated on farms and using this data for decision making. This is because genetic improvement programs generally carry out genetic assessments once or twice a year, on specific dates, depending on the availability of phenotype data from members and the availability of human and computational resources to carry out genetic assessments. However, this schedule does not always meet the needs of genetic selectors, who constantly generate phenotype data, but do not receive genetic evaluations in time to make selection decisions for their herds at the desired time. The development of a platform for integrated and automated data analysis will mitigate this problem, or even eliminate it, because it makes it possible to carry out evaluations in very short intervals (biweekly, monthly).

Four activities are necessary for the execution of Action 5. Sub-activities 5.1, 5.2 and 5.3 consist of the development of three modules for the data integration platform: "Production control"; "Genetic resources"; and "Economic evaluation", respectively. These modules can be developed from other models that already exist or that are being developed, or they can be entirely developed for the platform. In this case, in sub-activities 5.1, 5.2 and 5.3, studies should be carried out on the current stage of development with the partners. These modules should receive and process the data. Sub-activity 5.4 consists of integrating the modules (described above) in an online platform so that users can add to the database and obtain the data necessary for their activities. By adding their farm data to the platform, users (whether a technician or producer) contribute to the construction of a robust database. They also benefit from the data already available on the platform.

Table 92 – Action 5 and related activities

ACTION 5 – DEVELOPMENT OF A PLATFORM FOR DATA INTEGRATION AND ANALYSIS AND GENERATION OF REPORTS ON GENETIC IMPROVEMENT	
Sub-activity 5.1	Elaboration of the "Production control" module to import the data obtained in Action 1 for analysis and generating results reports
Sub-activity 5.2	Elaboration of the "Genetic resources" module for the execution of Action 3 (especially sub-activity 3.3)
Sub-activity 5.3	Elaboration of the "Economic evaluation" module for the execution of Action 4
Sub-activity 5.4	Integration of modules in an online platform where users can add to the database and obtain the necessary data for their activities

Source: the author.

Action 6 and related activities

Action 6 involves training technicians and producers to use genetic improvement, the dissemination of information on the technology and the proposition of changes to curricula to include genetic improvement in higher education institutions. This action consists of five activities.

The action involves developing teaching material, using language that is accessible to field technicians and users of genetic material, on the main concepts and actions to understand genetic improvement (sub-activity 6.1). As shown in the schedule, this activity can be carried out over the second year of the TAP, since it does not depend on any results to come. The material, as well as the other activities of the action, should be based on a communication plan with a view to identifying the target group, as well as promoting the TAP dissemination and training actions.

The team should also prepare a manual for using the platform and interpreting the results (sub-activity 6.2), with content that is effective for transmitting knowledge to users.

In addition to the production of teaching material, distance learning and classroom courses will be offered for technicians and producers (sub-activity 6.3), as well as events for the dissemination of results and for launching the platform (sub-activity 6.4).

These four initial actions require the collaboration of institutions with experience in the preparation of dissemination material and the training of human resources. The central idea is to develop material and use efficient methodologies for transferring knowledge and training human resources. The language of the material and training in this action should adhere to the communication plan (described above).

Sub-activity 6.5 is aimed at improving the qualification and engagement of future technicians in the area of animal genetic improvement. The experience and results from the execution of the TAP can be used to propose changes to course curricula in the area of animal genetic improvement, such as the mandatory and elective undergraduate courses offered on animal genetic improvement in Zootechnics, Veterinary Medicine and Agronomy degrees (and other courses in the specialties of Agrarian Sciences, Biological Sciences and others). Knowledge in these professions is constantly evolving, and educational institutions need to adapt to these changes to ensure their graduates are able to work in the labor market. To this end, this TAP can assist higher education institutions in the training of their students.

Table 93 – Action 6 and related activities

ACTION 6 – DISSEMINATION, TRAINING AND EDUCATION FOR TECHNICIANS AND PRODUCERS ON THE USE OF GENETIC IMPROVEMENT	
Sub-activity 6.1	Development of material, using language accessible to field technicians and users of genetic material, on the main concepts and actions to understand genetic improvement
Sub-activity 6.2	Creation of a user manual for the platform and the interpretation of results
Sub-activity 6.3	Provide two distance learning courses, with a 40-hour workload each, and two 16-hour classroom courses for technicians and producers
Sub-activity 6.4	Events to disseminate results and launch platform
Sub-activity 6.5	Elaboration, dissemination of guidelines and education for changes to courses on genetic improvement technologies for higher education degrees in Agrarian Sciences, Biological Sciences and others

Source: the author.

9.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

The implementation of the TAP depends on the collaboration of stakeholders from the public sector (educational, research and extension institutions and development agencies) and the private sector (genetic improvement programs, breeder associations, consultancy companies, genotyping laboratories, software development companies) with missions and functions aligned with the needs of the proposal presented below. Some of the potential TAP partner institutions are mentioned below. This does not mean that they are already committed, or that they are the only stakeholders capable of contributing to the implementation of the activities.

We propose that the TAP be managed by a Committee composed of a coordinator and advisory members. The coordinator could be a qualified technician (professor or researcher) linked to an institution with a support structure consistent with the needs of the project. The person should also have good relations with the other stakeholders required for the execution of the actions. It is essential that there are no conflicts of interest between the coordinator, his/her institution, the TAP and the other stakeholders involved. The other members would be TAP advisory partners, whether development institutions, TAP execution partners, or public or private stakeholders.

Initially, the Committee should prepare and approve a work plan, with a clear definition of responsibilities, work methodology and TAP management strategy. Committee members will be primarily responsible for creating a network of collaborators, defining responsibilities for actions and managing and monitoring the TAP stages.

Selecting a TAP coordinator is not important at this moment, but there are professionals from a number of national institutions (Federal University of Minas Gerais – UFMG, Universidade Estadual Paulista – Unesp, for example) who are capable of assuming the task. Similarly, the other members could be from development agencies (Mapa, CNPq, for example), breeder associations, genetic improvement programs and consulting companies. Universities and research institutes, research companies, rural extension and technological training and development agencies have extensive experience in the development and transfer of technologies, as well as in the training of human resources. Professors and researchers linked to these institutions routinely perform coordination and execution activities for projects similar to this one. Universities and research companies also have qualified technical staff (students, higher education technicians) to carry out some of the activities. Similarly, rural extension companies have established contacts with the potential beneficiaries of genetic improvement, and technological training companies have extensive knowledge of the methods and tools for disseminating the technology of the TAP. Within these institutions, there are highly qualified professionals involved in genetic improvement, beef production, economics and statistics that could be on the TAP team.

Agricultural management companies have important databases that could support the execution of some proposed activities, making them potential partners for the execution of TAP activities. Management companies, for example, assist commercial farmers in managing their businesses. They already have zootechnical and economic performance databases on hundreds of farms in the main meat producing regions in Brazil. These companies can contribute to the TAP by sharing the data in their databases or assisting in obtaining additional data.

Genetic improvement programs, such as the Embrapa Beef Cattle Genetic Improvement Program (Geneplus), are coordinated and run by qualified and experienced technicians. These programs are long-standing partners of breeders and breed associations. They promote genetic improvement in beef cattle, are aware of the specificities of genetic improvement and are trusted by the developers of this technology. They will be fundamental for planning and executing TAP actions and activities. Genetic improvement programs already employ data collection and processing routines, as well as having field technicians who interact directly with breeders. These data collection and processing routines can be used to support the execution of some TAP activities, and the field technicians are a great resource for training and disseminating information among genetic improvement developers and users.

Additionally, breeder associations could be both partners and beneficiaries of the TAP. These institutions have large genealogical and phenotype databases, necessary for studies on genetic variability and estimation of genetic parameters. They can also carry out field activities involving the collection of new phenotypes and interviews with breeders. Genetic improvement programs and breeder associations will be able to use the platform and the selection objectives to assist their members (selection farms) in decision making.

The results generated in this project will also be of interest to commercial producers who depend on superior genetic material for their operations. These partners can be major beneficiaries of the TAP and could finance some specific actions that generate results directly related to their business areas.

Although this TAP is predominantly technological and directed at agribusiness, its results also have a direct impact on other government sectors, such as the economy (Ministry of Economy – ME) and the environment (Ministry of the Environment – MMA). Thus, these two Ministries could also be important stakeholders in the TAP.

BNDES and the ME could act to raise awareness among the stakeholders required for the development of the TAP, as well as directly financing some actions. Furthermore, improving the genetic potential of beef cattle in Brazil will contribute to increasing the revenues of producers and tax revenues for the state.

Genetic improvement can also have a positive impact on environmental sustainability. This technology offers the chance to improve feed efficiency and reduce the environmental impacts of beef production. Given this potential, the MMA could be an important stakeholder for the development of the TAP, as well as finance some actions and mobilize other stakeholders.

Table 94 – Main stakeholders to involve in implementing the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Research groups in the areas of genetic improvement, beef production, statistics and economics from universities and research companies (Mapa, Embrapa, UFMG, UFV, Unesp and USP, among others)	Given their expertise in genetic improvement, they could act in the execution of TAP activities.
Agricultural management consulting companies	These agricultural management companies carry out cost and revenue studies in beef production. They have large historical databases on commercial farms. They could act as technical partners in sub-activities 1.1, 1.2, 2.2, 4.1, 4.2 and 6.2 to 6.4.
IBGE	The Brazilian Institute of Geography and Statistics is the country's main provider of data and information, serving the needs of different segments of civil society, as well as federal, state and municipal government bodies. It could provide data for the execution of sub-activities 1.1 and 1.3.
Producer associations, genetic improvement programs and commercial producers	These institutions/companies are responsible for the genetic improvement of cattle breeds or operate in the sector. They could act as technical partners to help identify breeders and apply the questionnaires in sub-activities 2.1 to 2.3. They could contribute to obtaining data and genetic material for the execution of sub-activities 3.1 and 3.2 and the elaboration of requirement documents for the execution of sub-activities 3.3, 5.1, 5.2, 5.3 and 5.4, as well as the dissemination of results and training in sub-activities 6.3 and 6.4.
Software development companies	They could act in the development of computational tools for sub-activities 3.3, 5.1, 5.2, 5.3 and 5.4.

continues

continuation

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Emater	In general, Technical Assistance and Rural Extension Companies (Emater) have the mission of "promoting sustainable rural development, coordinating, articulating and executing technical assistance and rural extension for the benefit of society" (EMATER-PR, [sd]). Emater companies could be responsible for the development of educational material and training human resources (sub-activities 6.1, 6.2, 6.3 and 6.4).
Sebrae	The mission of the Brazilian Micro and Small Business Support Service (Sebrae) is "promoting the competitiveness and sustainable development of small businesses and stimulating entrepreneurship" (SEBRAE, [s.d.]). It could act in the development of educational material and in training human resources (sub-activities 6.1, 6.2, 6.3 and 6.4).
ME	The Ministry of Economy could act in awareness raising activities among technology development stakeholders to help implement the TAP.
MMA	The TAP is directly related to the sustainability of beef production- a goal that aligns with the Ministry of Environment's mission of formulating and implementing national environmental public policies for sustainable development. It could support the monitoring of the execution of TAP activities.
Finep	The Financier of Studies and Projects (Finep) promotes science, technology and innovation in companies, universities, technological institutes and other public and private institutions. It participates throughout the innovation chain, focusing on strategic, structural and impact actions for the sustainable development of Brazil. It could act as a financing agency for TAP activities.
BNDES	BNDES is the main Federal Government instrument for long-term financing and investments in all segments of the Brazilian economy. It could act as a financing agent for TAP activities.
CNPq	CNPq promotes and fosters scientific and technological development in Brazil and contributes to the formulation of national science and technology policies. It could act to support the promotion of TAP activities.

Source: the author.

Schedule of actions and activities

The time frame for implementing the TAP is eight and a half years, a time believed adequate for the execution of actions that involve data collection in the field, development of data analysis and integration platforms, training of users and validation of the processes necessary for the development and diffusion of genetic improvement in beef cattle. The start of activities is scheduled for the second half of 2021.

Some actions can be carried out independently and in parallel, such as Actions 1 and 2. Sub-activity 1.1 is continuous, as it involves studying meat production costs and revenues. To avoid the effects of price fluctuations between years, we recommend this activity be carried out continuously over five years, ensuring more accurate data that is free of momentary price variations.

Action 3 involves the design of a field experiment for collecting animal data. Theoretically, this experiment could also start with previous actions. However, it is prudent to advance the understanding of the needs of producers (Action 2) and conduct a comprehensive bibliographical review to identify scientific issues that still need to be investigated before investing financial resources in the collection of new data.

The execution of Action 4 requires knowledge of the structure and part of the data obtained in Actions 1 and 2, principally. The completion of this action also depends on the analysis of the data obtained in Action 3.

Action 5 is the most complex, and its execution depends on knowledge of the structures of the data that will be added to the platform (type of data and files, amount of data, phenotypes collected, format of the genotype files). Thus, this activity requires the data and results obtained in previous actions before it can begin. The platform validation phases will be more effective if the previous actions (1 to 4) are already completed, or very close to it.

The execution of Action 6 can be broken down over the execution period. As this action essentially involves training technicians and platform users, some activities can be carried out as soon as the previous actions have been completed, or at least with the first results of the project.

The sub-activities that involve data collection in the field (1.1 and 3.1) or development of computer systems for data integration and analysis (3.3, 5.1, 5.2, 5.3 and 5.4) require longer execution periods. Thus, it is important to develop an efficient strategy for monitoring and managing activities and their results.

Table 95 – TAP implementation schedule

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
1.1	■	■	■	■	■	■	■	■	■	■								
1.2	■	■																
1.3	■	■																
2.1		■																
2.2		■	■															
2.3		■	■															
2.4			■															
3.1			■	■	■	■	■	■										
3.2					■	■	■											
3.3						■	■	■	■									
4.1						■	■	■	■									
4.2								■	■	■	■							
5.1										■	■	■	■	■	■			
5.2										■	■	■	■	■	■			
5.3										■	■	■	■	■	■			
5.4												■	■	■	■	■	■	
6.1			■	■				■	■					■	■	■	■	
6.2			■	■				■	■					■	■	■	■	
6.3																■	■	
6.4				■					■								■	
6.5															■	■	■	

Source: the author.

9.5. TAP implementation costs and financing options

The total cost of the TAP was estimated at approximately BRL 9.4 million. Actions 3 and 5 each account for approximately 35% of the budget. They are complex actions and largely dependent on specialized and outsourced services.

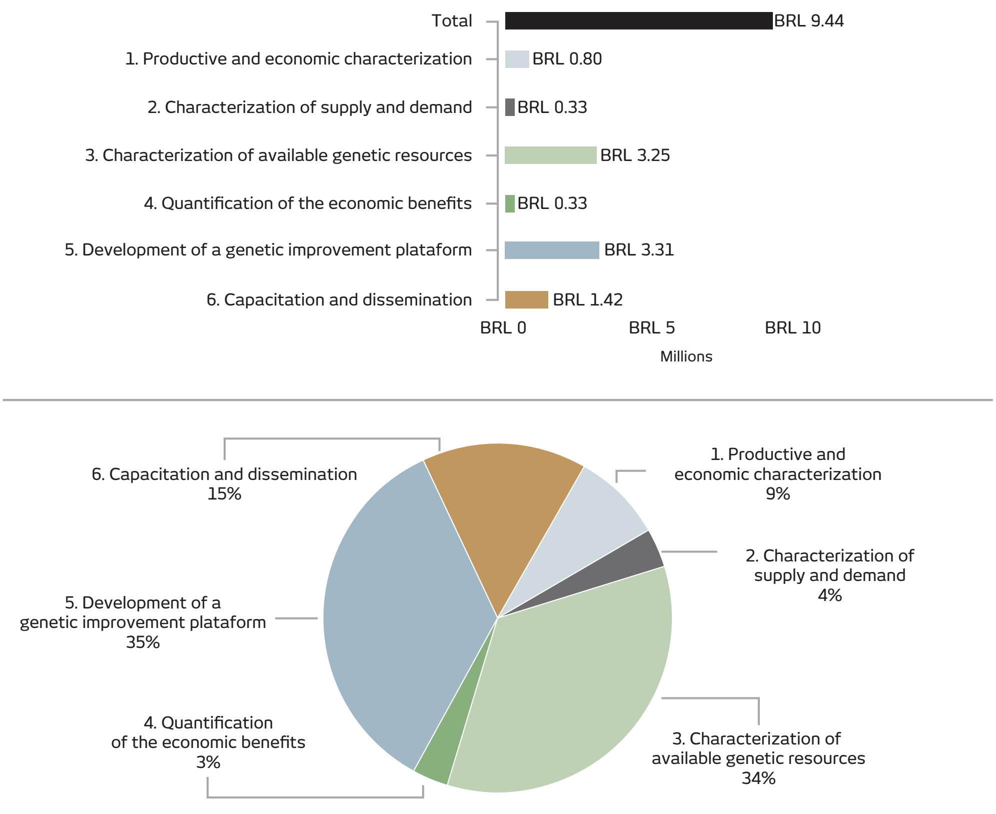


Figure 23 – Total cost per action, in millions of BRL and as a percentage, for the TAP for genetic improvement in beef cattle

Source: the author.

With respect to potential sources of financing for the activities, and with a view to financial results and a focus on research and development, we determined the typical means of financing would be non-repayable loans and technical assistance. Financing is accessible for state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and in the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b).

9.6 Risk and contingency plan

Defining risk and contingency plans is not a trivial task. Analyzing previous initiatives, and their successes and failures, was important in this stage. We sought to adequately define each action and activity (presented above), as well as the complexities, costs and impacts. Potential barriers to the implementation of the TAP, and the consequences of non-execution, were also assessed. We considered political, institutional, organizational, technical and cost risks. They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs). Additionally, the relevance of the actions to achieve the proposed objective was also considered in the definition of the level of risk. Finally, we proposed contingency actions to eliminate or mitigate potential risks. High risks were associated with sub-activities 3.2, 3.3, 5.1, 5.2, 5.3 and 5.4.

Sub-activities 3.2 and 3.3 are both associated with the five risk categories (cost, technical, organizational, institutional and political). These activities account for approximately one third of the TAP budget and are subject to the following risks: currency exchange rate variations can affect the cost of the required inputs (cost risk); they must be carried out by highly qualified personnel (technical risk); they are subdivided into stages that depend on different stakeholders and organizations, requiring a high level of control and coordination (organizational risk); and they need to be carried out by stakeholders from different public and private institutions that may have different objectives and views (institutional risk). There is also a political risk, represented by potential conflicts of interest in selecting the breeds to be studied and, especially, how the data will be used. To illustrate this conflict of interest, it is worth noting that sub-activity 3.2 involves the genotyping of animals. In general, animal owners provide genetic material (hair, blood or semen for DNA extraction) at no cost. Genotyping is paid for with public resources. The genotypes are used for research, but there are restrictions on the transfer of that genotype to the database of the breeding program that provides consulting services for the breeder who provided the material for genotyping. The poor definition of responsibilities and data sharing and use has been (and still is) a cause of conflicts of interest. As a means of eliminating or mitigating these risks, we propose: contingency actions to objectively select the breeds for study (considering their relative importance in beef production); to agree and register, officially and in advance, how to share the data, information and royalties generated in the project, clearly specify services, costs and lead times; contract qualified and experienced personnel and companies to carry out the activities; sign contracts with rights, duties and penalties of the parties involved; contract external experts to validate activities and data; and maintain efficient methods of communication between stakeholders and management.

Sub-activities 5.1, 5.2, 5.3 and 5.4 are also subject to all the risk categories cited above, and at a high level. Together, the costs of these activities account for approximately one third of the estimated budget (cost risk), with a high degree of uncertainty in the definition of costs and potential financing and partners for the ongoing maintenance and validation of the platform (institutional risk). The different financing agents may have different objectives, which can lead to conflicts of interest (institutional and political risks). The actions require detailed specifications of the types of data that will be used on the platforms, the procedures that must be performed, and the functionality of the products (platforms) that need to be delivered (technical risk). They also depend on efficient coordination, especially for defining requirement documents and meeting deadlines (organizational risk). They are also the most complex and difficult TAP actions, which, until now, have never been implemented on the intended scale. To maximize the chances of success, it is essential to clearly specify the role of each participant; maintain efficient communication; define targets and the people responsible for them; monitor the execution of activities; contract experienced and qualified institutions and personnel in the areas of genetic improvement and software development; establish contracts with rights and obligations of service providers, as well as penalties for non-compliance of duties; and organize workshops to validate the modules and platforms developed.

Table 96 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1 Conduct a study on production, economic, physical and climatic indicators and production profile of 300 farms in the main beef producing regions of Brazil	Technical risk and organizational risk	There are few companies with available data and each company uses a different methodology for data collection and analysis. In addition, there is the challenge of finding qualified labor for the project technical team, particularly the role of technical coordinator to conduct activities.	Medium	Contract companies with experience in the area. Identify what types of data are collected by each company before entering into partnerships. Contract technical staff with extensive experience in the area from leading research centers and universities.
1.2 Develop and standardize a methodology for calculating and analyzing data from additional indicators with the ability to characterize and discriminate production systems		There are many indicators for analysis, but not all of them are used on farms. Lack of cooperation between the contracted professionals and the technical coordination of the project.	Low	Contract an experienced team to coordinate the activity. Define robust indicators (variables) and statistical methods. Hold quarterly team meetings with the technical coordination of the project. Hire technical staff with extensive experience in the area from leading research centers and universities.
1.3 Quantify the contribution (absolute and relative) of each production system (groups of farms identified in sub-activity 1.1) to total beef production in Brazil		There are many methods for classifying production systems, and sampling can impact the profile of the sampled production systems. Lack of qualified labor. Lack of cooperation between the contracted professionals and the technical coordination of the project.		Properly characterize the production systems. Ensure the representativeness of the sample of farms. Use data from the Agricultural Census to assist in the interpretation of results. Hold quarterly team meetings with the technical coordination of the project. Hire technical staff with extensive experience in the area from leading research centers and universities.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
2.1 Analysis of available results and identification of locations and sample to characterize strategies of meat producers and genetic material suppliers	Technical risk and organizational risk	Errors in the analysis of data resulting in the selection of inappropriate locations. Lack of coordination in the activity and difficulty contracting qualified labor.	Low	Contract research support foundations from leading RD&I centers. Contract technical coordinator to prepare the Terms of Reference. Supervise and prepare the research forms.
2.2 Characterize strategies used by meat producers to acquire genetic material (development and application of research on farms)	Technical risk	Respondents may have difficulty understanding the terms used in the questionnaire. The answers may not reflect reality. Errors in data tabulation.		Prepare an objective questionnaire, including questions to validate the quality of the information. Develop a glossary of technical terms and a tutorial for filling out the form. Supervise the application of the research.
2.3 Characterize strategies used by genetic material suppliers in their production systems, and compile and analyze a database with genealogy, birth and genetic values of animals (research on farms that produce and supply genetic material)				
2.4 Analysis and interpretation of the results of sub-activities 2.2 and 2.3 to generate a report on genetic improvement opportunities	Technical risk and political risk	Difficulty interpreting the results of the two previous activities. Potential conflicts of interest. Delays in producing the report.		Develop the two forms to be used in the previous activities together. Clearly define partner obligations and benefits. Define the strategy for the dissemination of results. Establish the deadline for the delivery of the report in the contract.

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
3.1 Identification of new selection criteria for the main breeds of beef cattle. Construction of a database with important new characteristics and estimation of genetic parameters for the design of genetic improvement programs	Cost risk, technical risk and organizational risk	Potential changes in the costs of third-party services. Difficulty finding qualified labor to carry out the activity. Lack of technical coordination in the studies. Delays in building the database.	Medium	Contract a technical partner with extensive experience in the activities. Establish contractual clauses that fix the cost of activities and penalties for delays. Validate the results of the activity and the database with a specialist. Contract professionals from leading research centers in the area.
3.2 Characterization of genetic variability in the main breeds of beef cattle. Construction of databases (genotypes and genomes) and characterization of the genome of the main breeds of beef cattle	Cost risk, technical risk, organizational risk and political risk	Potential changes in the costs of third-party services. Difficulty finding qualified labor to carry out the activity. Lack of technical coordination in the studies. Delays in building the database. Potential conflicts of interest in selecting breeds and how the data generated is used.	High	Define objective criteria for identifying the breeds to study. Clearly define how the data generated will be used. Define the sharing of royalties. Contract a technical partner with extensive experience in the activities. Establish contractual clauses that fix the cost of activities and penalties for delays. Validate the results of the activity and the database with a specialist. Hire professionals from leading research centers in the area.
3.3 Development of routines and software for data collection and storage for statistical analysis of phenotypes (sub-activity 3.1) and genotypes (sub-activity 3.2), and to identify regions of the genome associated with the characteristics of interest	Technical risk, organizational risk, institutional risk and political risk	The activity is complex, as it depends on many stakeholders and detailed tasks. Potential conflicts of interest between participants. Difficulty identifying a leader for coordination. Delays in software delivery.	High	Clearly specify the role of each participant. Ensure efficient communication. Define targets and the people responsible and monitor the execution of activities. Clearly define tasks. Contract experienced service providers. Register partnerships (in contracts). Establish contractual clauses that establish penalties for delays.

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continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
4.1 Development and implementation of a methodology for calculating the economic values of the characteristics mapped in previous activities	Organizational risk and technical risk	Difficulty integrating the necessary data in the process. The beneficiaries themselves, in some situations, do not contribute to the dissemination and effective use of the results, because this can lead to a change in the way genetic material is commercialized. Lack of validation of the methodology.	Low	Contract work groups that can cooperate and interact with different links in the beef production chain. Contract technical partners with extensive expertise in the area. Contract a specialist to validate the methodology.
4.2 Quantification of the economic, environmental and production benefits of using superior genetic material (selection), as well as different pairing systems (crossbreeding) on 50 farms	Technical risk and organizational risk	Difficulty obtaining robust data. Lack of technical coordination and understanding of the methodology developed in sub-activity 4.1. Poor elaboration of forms for data collection.		Identify farms for data generation. Conduct a thorough literature review to obtain additional data. Hold meetings with the technical coordinator and the sub-activity 4.1 team to clarify the methodology and research form questions.

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
5.1 Elaboration of the "Production control" module for the data obtained in Action 1, as well as analysis and the production of results reports	Technical risk, organizational risk, institutional risk, political risk and cost risk	The activity is complex and depends on many stakeholders and on detailed tasks. Potential conflicts of interest between the participants. Lack of qualified labor for technical coordination. Delays can jeopardize the development of the integrated platform. Lack of stakeholder interest in the validation of the modules.	High	Clearly define the role of each participant. Ensure efficient communication. Define targets and the people responsible and monitor the execution of activities. Contract technical staff from leading centers in the areas of genetic improvement and software development. Establish penalties for non-compliance of deadlines in the contract. Organize validation workshops by module.
5.2 Elaboration of the "Genetic resources" module to execute Action 3 (especially sub-activity 3.3)				
5.3 Elaboration of the "Economic evaluation" module to execute Action 4				
5.4 Integration of modules in an online platform where users can add to the database and obtain information necessary for their activities				

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
6.1 Development of material, using language accessible to field technicians and users of genetic material, on the main concepts and actions required to understand genetic improvement	Organizational risk and technical risk	Poor identification of the target group and inadequate communication guidelines. Language not adequate for users. Lack of supervision of the materials produced. Delays in delivery.	Low	Contract partners with experience in technology transfer and production of accessible content. Contract a diversified team, including an activity supervisor with extensive experience in training, dissemination and communication actions. Establish contractual penalties for delays in the delivery of materials. Prepare and monitor the communication plan.
6.2 Development of a user manual for the platform and for the interpretation of the results generated		Lack of knowledge of the platform's applications. Language not adequate for users. Lack of supervision of the materials produced. Delays in delivery.		Involve Action 5 team members. Contract partners with experience in technology transfer and production of accessible content. Contract a diversified team, including an activity supervisor with extensive experience in training, dissemination and communication actions. Establish contractual penalties for delays in the delivery of materials.
6.3 Provide two distance learning courses, with a 40-hour workload each, and two 16-hour classroom courses for technicians and producers	Organizational risk	Unable to disseminate the data and knowledge to the main users of the technology. Inability to convince potential beneficiaries.	Low	Define a training plan that involves activities that attest to learning and provide certificates after completion. Contract experienced partners for conducting courses and opinion leaders to plan and execute activities. Present robust and reliable data on the benefits of the technology.

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continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
6.4 Events for results dissemination and platform launch	Organizational risk and institutional risk	Delays in delivering results. Lack of stakeholder interest.	Low	Supervise deliveries through technical coordination. Establish contractual penalties for delays. Elaborate communication and stakeholder engagement strategy.
6.5 Elaboration, dissemination of guidelines and education for updating course curricula on genetic improvement technologies in higher education degrees in Agrarian Sciences, Biological Sciences and others	Institutional risk and organizational risk	Lack of engagement by teachers not used to digital teaching resources. Difficulty understanding the educational objectives. Difficulty contracting specialized labor.	Low	Train teachers who will prepare the proposal in the area and on project results. Contract specialized labor for formulating higher education proposals. Carry out engagement activities at universities, based on the communication plan for the training and dissemination action.

Source: the author.

10.

Technology Action Plan **for Silviculture and Genetic Improvement of Native Species**

10. TECHNOLOGY ACTION PLAN FOR SILVICULTURE AND GENETIC IMPROVEMENT OF NATIVE SPECIES

10.1. Definition of technology

In the new technological paradigm, productivity gains in production processes, energy efficiency and improvements in product quality are requisites for competitiveness and, as a consequence, for gaining market share, especially in the global market.

In this context, the forestry sector shows promising potential. Although native tree species forestry has relatively long production cycles in Brazil, this activity has great potential for development and offers economic, social and environmental benefits, especially when considering the multiple uses of planted forests. The benefits include conservation of natural resources, soil, water and fauna, among others.

The starting point for realizing these benefits is the implementation of genetic improvement and management programs for tree species with economic potential, and obtaining seeds from these trees with genetic quality to meet the needs of forest sector industries in a sustainable manner, with potential for income generation and the social well-being of Brazilian farmers. This technology also has significant potential for mitigating GHG emissions by increasing carbon stocks and providing ecosystem services. In addition, the use of native trees in reforestation is expected to improve the processes of generating and storing water in soil, increase the matrix of wood uses and alleviate pressures on the remnants of native vegetation in Brazilian biomes.

Additionally, native tree silviculture is expected to increase carbon stocks in soil, especially compared to traditional plantations of exotic species (typically species of *Eucalyptus*, *Corymbia* and *Pinus*). This is due to the co-evolutionary symbiosis between native tree species and the soil microorganisms that constitute the living part of the soil, which are able to store carbon in the form of microbial carbon. It is important to note that this association varies according to the tree species. In addition to carbon, some associations between legumes and carbon fixing bacteria (and legumes and mycorrhizal fungi) are able to increase the availability of nitrogen and phosphorus, respectively, in soil for plants.

It should be noted that the storage of carbon, nitrogen, phosphorus and other soil nutrients, as well as the recycling processes from the actions of soil microorganisms, improve the functioning of ecosystems by favoring greater biodiversity of flora and fauna.

10.2 Scope and goals

The biodiversity of Brazilian tree vegetation has very distinct phytophysiognomic characteristics in the six terrestrial biomes: Amazon, Cerrado, Atlantic Forest, Caatinga, Pantanal and Pampa. Among these, the first four are prioritized in this TAP, considering that Pantanal tree flora is largely composed of species that migrated from the Cerrado and the Amazon, and the Pampa native flora is mostly composed of grasses.

When considering the implementation of strategic actions for the sustainable use of forest resources in the four prioritized biomes, special attention should be given to tree species from the Cerrado and the Atlantic Forest, given that these are the two Brazilian biomes listed among the 25 global hotspots studied by Myers et al. (2000) that require more urgent public and private actions.

Although the Amazon and Caatinga biomes are not on the list of global hotspots, their importance for these actions should also be considered. The Amazon biome, with its vast biodiversity and number of endemic species, should be prioritized due to its strategic importance for food security and the supply of raw materials for forest-based industries. Nevertheless, the importance of the Caatinga must be understood in the context of its vulnerability from anthropic pressures and increasing aridity due to significant environmental changes (SILVA; RYLANDS; FONSECA, 2005).

The diversity of tree species in these biomes allows for selecting species for the planting and management of forest stands for the production of wood and non-wood products that can provide income and socio-environmental benefits. However, the low level of technological development in silviculture hinders the effective and efficient production of these species, compromising the attainment of targets.

The scope and goals of this TAP address the need for improving technology in silviculture to make better use of the diversity of native tree species.

Since these are native tree species, which require a rotation time greater than eight and a half years (the time frame of this TAP), with reproductive cycles that can exceed this period, it is feasible to expect that, within this period, it will be possible to obtain data for developing production prognosis models and to validate hypotheses, even if early, that can guide decision making for operating silviculture systems and for the implementation of genetic improvement programs.

However, the TAP also offers an important opportunity to support the development of technologies to foster Brazilian forestry. The great challenge is the long term development and diffusion of these technologies. We expect this challenge to be overcome with ongoing complementary data and analysis, conducted after 2030, aimed at revising the models and generating new scientific knowledge.

Table 97 – TAP scope and goals

SCOPE	GOALS
Implement genetic improvement programs and continue existing ones, as well as develop and improve silviculture technologies for native tree species of Brazilian flora that have high (current or potential) value and generate economic, social and environmental benefits.	By 2030, implement genetic improvement programs for at least ten naturally occurring tree species in Brazilian biomes and develop silviculture technologies so that, in synergy with the genotypes selected, they can make forestry enterprises economically viable.

Source: the author.

10.3. Actions and activities

Critical gaps and barriers and means to overcome them

We analyzed the barriers to the development of silviculture and the genetic improvement of selected native species and determined the main critical barriers to the dissemination of the technology, considering the project's 2030 deadline.

We identified four critical barriers to the implementation of TAP. Three are economic and market barriers and one is a technological and scientific barrier. To overcome these barriers, we propose the implementation of genetic improvement programs by 2030 for at least ten naturally occurring tree species in Brazilian biomes and the development of silviculture technologies so that, in synergy with the genotypes selected, they can make forestry enterprises economically viable.

Prioritized critical gaps	Prioritized barriers	Goals
ECONOMIC VALUE OF TIMBER AND NON-TIMBER PRODUCTS	Rejection of juvenile wood produced by the native tree silviculture system	By 2030, implement genetic improvement programs for at least ten naturally-occurring tree species in Brazilian biomes and develop silviculture technologies so that, in synergy with the genotypes selected, they can make forestry enterprises economically viable
DEFINITION OF POPULATIONS BY SPECIES OF INTEREST	Long term for achieving productivity gains	
COMBINED PROVENANCE-PROGENY TESTS	High implementation costs for forestry improvement programs	
SEED PRODUCTION	Low level of confidence of entrepreneurs due to insufficient technological content	
SELECTION OF INDIVIDUALS	Technology readiness level of concept validation only in native species genetic improvement laboratories (TRL 3)	

Figure 24 – Critical gaps and barriers and priority goals

Source: the author.

Actions and activities

The TAP actions for the development of silviculture techniques adhere to the concepts of equine forestry. As the target species for studies and technological development will only be defined after initial evaluations based on specialized literature, expert opinions and on the experience of teaching and research institutions (public and private), the nature of the cultivation system, whether pure or mixed, will depend on the knowledge of their ecological succession under natural conditions.

Once the ten target species are defined, the actions and activities (discussed below) should, as a priority, be carried out simultaneously in order to optimize the study period for a given species, or specific groups of species. Clearly, some of these actions and activities cannot be carried out simultaneously, since some depend on the completion of another. For example, market studies can only begin after characterizing the properties of juvenile wood, its potential uses and the implementation of demonstration units.

Each action is composed of a set of activities for the step-by-step execution of the TAP.

Action 1 and related activities

Action 1 consists of four activities. The first is aimed at defining the ten target species for study and technological development. The definition of these species requires characterizing the technological properties of the wood and potential uses, as well as studying previous applications, experiences and silviculture outcomes when cultivated in equine forestry in pure or mixed planting systems. The selection of species should also consider the economic, social and environmental context of the biome where it is located. The criteria for classifying species in each biome should be determined by specialists in the fields of wood science, ecology, forest management, silviculture and genetic improvement. It should be noted that at least one species will be selected from each biome, following a priority classification. However, the number of selected species per biome can vary.

Perhaps the main prerequisite for selecting the species per biome is the level of technological development in silviculture and improvement of the species being evaluated. One can cite, for example, the Brazilian pine (*Araucária angustifólia*) in the Atlantic Forest; candeia (*Eremanthus erythropapus*) in the Cerrado; the Brazil nut tree (*Bertholletia excelsa*) in the Amazon; and the umbuzeiro (several species of the genus *Spondias*) in the Caatinga.

We included studies on the technological properties of juvenile wood, reported in the activities of Action 1, for the following reasons:

1. Although the literature contains important scientific information on the wood of Brazilian tree species, most of it refers to the properties of wood from mature uncultivated trees (wood produced over decades or even centuries) that has a high ratio of adult wood to juvenile wood;

2. This TAP is aimed at the production of trees for reforestation that are relatively young and, thus, produce wood with a high ratio of juvenile wood. Juvenile and mature wood have different anatomical, physical, mechanical and chemical properties that often determine their uses;

3. The production of juvenile wood also adheres to the universal concept that its technological properties and potential uses derive from the desired phenotype (F) improved environmental conditions (E), adopting good silviculture practices and improving the genetic makeup of the trees (G) (genetic improvement). Additionally, the interaction of G by E must be taken into account, considering the significant environmental variations between and within biomes.

The activities that follow the selection of priority species (sub-activity 1.1) are aimed at evaluating the technological properties of juvenile wood and its adaptation for industrial, commercial and other uses (sub-activity 1.2), as well as the construction of demonstration units for its use (sub-activity 1.3) and subsequent market research to determine the degree of acceptance of wood and non-wood products, with a focus on the characterization of technological innovations (sub-activity 1.4).

Table 98 – Action 1 and related activities

ACTION 1 – EVALUATION OF TECHNOLOGICAL PROPERTIES AND DEGREE OF MARKET ACCEPTANCE OF JUVENILE WOOD FROM NATIVE TREE SPECIES FOR CULTIVATION	
Sub-activity 1.1	Survey of the current best knowledge on the technological properties and studies of the use of juvenile woods to select ten target species for study from the Amazon, Cerrado, Atlantic Forest and Caatinga biomes
Sub-activity 1.2	Evaluate the chemical, anatomical, physical and mechanical properties of juvenile woods to adapt them for industrial, commercial and other uses
Sub-activity 1.3	Using juvenile wood from the target species, build 60 demonstration units for use in the artisanal production of decorative objects; furniture industry; and construction industry
Sub-activity 1.4	Conduct market research to assess the degree of acceptance of demonstration units for the use of juvenile wood (sub-activity 1.3) and characterize the technological innovation

Source: the author.

Action 2 and related activities

This action has three activities. Sub-activity 2.1 is aimed assessing the market value of wood and non-wood products to provide subsidies to guide the subsequent activities focused on improving the quantity and quality of products with greater added value.

Sub-activity 2.2 seeks to select populations of each target species, which may come from superior seeds and have broad intra-population variation for the phenotype selection of parent trees (matrices). From these two selections, the genetic tests (combined provenance-progeny tests) in sub-activity 2.3 will be carried out, as well as on individuals within the progeny. It should be noted that at least one species will be selected from each biome, with their respective origins and progenies, and that the number of species per biome may vary.

Preferably, these tests should be carried out in the four study biomes. In the case of test environments outside the natural habitat of the species, the correspondences between the source and destination environments should consider edaphic and climatic variables. From the analysis of correspondences and data from the tests, over the years, the phenotypic plasticity of each progeny and provenance will be known, allowing for the definition of the environmental range for cultivation of the genetic materials to be selected and the generation of models for future assisted migration plans.

Table 99 – Action 2 and related activities

ACTION 2 – IMPLEMENTATION OF COMBINED PROVENANCE-PROGENY TESTS WITH EXPERIMENTAL UNITS OF HALF-SIBLINGS OR CLONED PLANTS FROM A MOTHER PLANT (MATRIX), FOR SPECIES THAT CAN BE PROPAGATED VEGETATIVELY	
Sub-activity 2.1	Estimate of economic values of wood and non-wood products in the domestic and international markets
Sub-activity 2.2	Select populations (provenance) and mother plants (matrices) within populations for combined provenance-progeny tests
Sub-activity 2.3	Implement the aforementioned tests in four different environmental zones, considering the edaphic and climatic characteristics prevalent in the Amazon, Cerrado, Atlantic Forest and Caatinga biomes

Source: the author.

Action 3 and related activities

This action has two activities (see table below). Sub-activities 3.1 and 3.2 are complementary, and also complement sub-activity 2.3. They can be carried out concurrently to save time in this initial genetic improvement phase.

The seeds harvested from the selected populations and matrices will be sent to the seedling production nursery in sufficient quantities for the implementation of the tests in sub-activities 2.3 and 3.1. For each prioritized species, the seedlings will be divided into two lots, one for conducting sub-activity 2.3 and the other for sub-activity 3.1, which should be implemented in the four biomes.

Environments outside the natural habitat should be as similar as possible to the habitat of the species, considering the edaphic and climatic variables closely related to survival and productivity. Sub-activity 3.1 refers to a maximum of 40 seed production units (ten species in each of the four biomes). The maximum of 40 units is to avoid a situation where one of the selected species may not be adequate for another biome (for example the Brazilian pine *Araucária angustifólia* from the Atlantic Forest would not thrive in the Caatinga).

In planning the implementation of production plantation units, the reproductive system, the type and mode of reproduction of the species, should be considered to determine the type of plantation (seed or clone) and spatial distribution to minimize endogamy and maximize pollination and seed production. In plantations of a given species grown in a biome outside its natural range, one should observe the level of correspondence between the edaphic and climatic variables between the natural habitat of the species and the habitat of the plantation area.

It should be noted that when the cloning process is unknown for a species, the experimental units and seed production units (plantations) should consist of plants of seminal origin. On the other hand, for species with a known cloning process, these units and plantations should consist of cloned seedlings.

Sub-activity 3.2 will be carried out after obtaining and analyzing annual data on the productivity and quality of the desired products. Progeny trees that fail genetic tests will be thinned annually to transform untested seed production units into tested ones with genetic gains.

The definition of the quantity of seed producing trees per selected progeny should be based on forecasts of the quantity of seeds to be produced. In the absence of this data, the reproductive capacity of the species, the level of seed predation and the size of the seeds should be considered.

Table 100 – Action 3 and related activities

ACTION 3 – IMPLEMENT EARLY SEED PRODUCTION PLANTATIONS USING SEXUAL OR ASEXUAL REPRODUCTION (DEPENDING ON THE SPECIES)	
Sub-activity 3.1	Concomitantly with the implementation of the combined tests (Action 2), implement 40 untested seed production plantations, using seedlings of clonal or seminal origin from each sampled matrix
Sub-activity 3.2	Initiate thinning of progeny trees that fail the provenance-progeny tests (Action 2) to transform the untested seed production plantations into tested ones, using annual data obtained in the tests

Source: the author.

Action 4 and related activities

This action is fundamental for the development of the technology, since the morphological, physiological and biochemical qualities of the seeds and seedlings produced for the processes and subsequent studies will ensure the attainment of the intended results. These qualities are highly correlated to the resilience of plants when faced with variations in environmental conditions.

Sub-activity 4.1 aims to establish the necessary protocols for recognizing seed quality for the seedling production process. Errors in the work of collecting, transporting, processing and storing seeds can have harmful consequences for germination and plant health. However, obtaining the first seeds from the selected populations and matrices can only be carried out following the protocols developed for the target species. In their absence, protocols developed for other species or groups of species that produce seeds with similar properties should be used.

The results from sub-activity 4.2 will allow for the development of more specific protocols for each of the ten species, since the physiological and biochemical studies required for stored seed quality assessments will be conducted in this activity.

Sub-activity 4.3 is aimed at the development or adaptation of protocols for assessing the quality of seedlings and trees using morphological, physiological and biochemical analysis. These protocols not only evaluate the methodologies for the production of seedlings and trees, but will be useful for genetic improvement programs, given the importance of knowing the genetic variations between and within populations for tolerating and reacting favorably to environmental stresses.

Table 101 – Action 4 and related activities

ACTION 4 – STUDIES OF SEEDS AND SEEDLINGS TO IMPROVE PERFORMANCE IN THE FIELD	
Sub-activity 4.1	Establish protocols for the collection, transportation, processing and storage of seeds for each of the selected species
Sub-activity 4.2	Develop or adapt protocols for the control of seed quality using physiological and biochemical studies in relation to long-term storage, dormancy, germination and plant health
Sub-activity 4.3	Develop or adapt protocols for quality control of seedlings in the nursery and trees in the field using morphological, physiological and biochemical studies for determining tolerance / resistance / resilience to biotic and abiotic stresses

Source: the author.

Action 5 and related activities

Action 5 includes three activities related to studies for the development of nutrition processes for seedlings and trees grown in the field. All the activities adhere to the common methodologies in agronomic plant nutrition studies, whether soil crops or for forest use. In the case of the latter, seedling production should adhere to those for field crops or for grafting processes (rootstock grafting) and in clonal multiplication systems, either by tissue culture or by mini-cutting (using hydroponic or semi-hydroponic processes).

Sub-activity 5.1 involves the study of the macro- and micro-nutrient needs of the tree species and how deficiencies or excesses can affect production and phytotoxicity. In parallel to this activity, sub-activity 5.2 seeks to develop specific mineral nutrition programs for each species, at different ages, and for nursery and field phases.

Following the implementation and results of sub-activity 5.1, sub-activity 5.3 should be implemented. This activity involves generating data and images that can quickly assist in the diagnosis of deficiencies or toxicity so that mitigating measures can be taken to ensure the healthy growth of seedlings and the productivity of trees in the field.

Table 102 – Action 5 and related activities

ACTION 5 – DEVELOPMENT OF SPECIFIC MINERAL NUTRITION PROGRAMS FOR SEEDLINGS IN THE NURSERY AND TREES IN THE FIELD	
Sub-activity 5.1	Assess the need for mineral elements (macro- and micro-nutrients) of each target species for seedlings in the nursery and trees in the field
Sub-activity 5.2	Develop specific mineral nutrition programs for each of the ten target species
Sub-activity 5.3	Define a methodology for diagnosing nutritional deficiencies using visual analysis of organs for seedlings in the nursery and trees in the field

Source: the author.

Action 6 and related activities

Action 6 and the four associated activities are based on the principle that great successes in the reforestation and genetic improvement of exotic (and some) native species cultivated in Brazil can be used or adapted for the development of silviculture technologies and the genetic improvement of the ten target species in the TAP.

Sub-activity 6.1 evaluates the applicability of ecological zoning for reforestation of exotic and native species. After assessing correspondences between the edaphic and climatic variables (defined in zoning for the cultivation of these species and those predominant in native species natural habitats) and their nutritional needs (Action 5), one can validate current zoning or propose specific zoning.

The zoning in sub-activity 6.1 is also intended to develop strategies for the implementation of genetic improvement programs, studies on phenotypic plasticity and generate models for assisted migrations of genotypes from a given biome to regions with similar characteristics in other biomes. An example of the latter is the rubber tree (native to the Amazon biome), which has clones that can be cultivated in other biomes, such as the Atlantic Forest and Cerrado.

In the context of technological development of traditional species in Brazilian silviculture with respect to vegetative multiplication (cuttings or tissue culture), sub-activity 6.2 is important for defining, establishing and improving cloning protocols for some of the target species, the development of clonal forestry and genetic improvement.

Sub-activity 6.3 involves analyzing market research methodologies for timber products from known and studied species aimed at adapting them to evaluate markets for the same products originating from planted forests.

The elaboration of plans to monitor and control pests and plant diseases is quite laborious and complex. Sub-activity 6.4 seeks to assess the applicability of plans developed for traditional tree species in Brazilian forestry, which can be used or adapted for monitoring and controlling potential pests and diseases in the cultivation of the selected native species.

Table 103 – Action 6 and related activities

ACTION 6 – ESTABLISHMENT OF SILVICULTURE AND GENETIC IMPROVEMENT STRATEGIES BASED ON EXPERIENCES FROM STUDIES OF TREE SPECIES WITH MORE TECHNOLOGICAL CONTENT	
Sub-activity 6.1	Evaluate the applicability of edaphic-climatic zoning developed for the cultivation of traditional tree species in reforestation practices in Brazil
Sub-activity 6.2	Test mini-cutting and tissue culture cloning using protocols developed by research institutions for the cultivation of traditional tree species
Sub-activity 6.3	Develop or adapt market research methodologies for wood and non-wood products from native tree species in this project
Sub-activity 6.4	Evaluate the applicability of the knowledge from projects for monitoring and controlling pests and diseases of traditional tree species cultivated in Brazil

Source: the author.

Action 7 and related activities

Action 7 has two activities. Sub-activity 7.1 is aimed a disseminating the quarterly results related to costs, production and profitability in forestry projects with native tree species and the commercialization of the products obtained in the activity. The presentations will be organized in extension projects to demonstrate silviculture techniques and processing of the generated products on small scale cultivation of the tree species. Sub-activity 7.2 involves the elaboration of an online platform to disseminate the results of the actions and techniques. Finally, sub-activity 7.3 involves an additional methodology for disseminating the results. All the knowledge from the silviculture and genetic improvement studies, including those related to the science and technology of wood and non-wood products from juvenile wood produced in plantations of the ten native tree species, will be used to develop content and curricula for mandatory and elective undergraduate courses and graduate courses or for distance education courses.

Table 104 – Action 7 and related activities

ACTION 7 – ELABORATION AND PROVISION OF EXTENSION AND TRAINING PLANS FOCUSING ON NATIVE TREE SILVICULTURE TECHNOLOGIES AND MARKET POTENTIAL	
Sub-activity 7.1	Develop, implement and conduct small-scale crop testing aimed at demonstrating silviculture techniques, processing wood and non-wood products and disseminating productivity results (with cost, production and profitability data)
Sub-activity 7.2	Develop an online platform to disseminate the techniques, products and results of the activities
Sub-activity 7.3	Elaboration and dissemination of guidelines for the development of elective courses and the provision of distance learning courses on silviculture technologies and genetic improvement of native species

Source: the author.

10.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

Recently, a number of organizations from the public, private and non-governmental sectors have shown a growing interest in scientific and technological development for the implementation of native forest species crops and uses in Brazil, especially in the Amazon, Cerrado, Atlantic Forest and Caatinga biomes. This interest has grown due to the potential and importance of native species for traditional regional uses (logging and non-logging uses) and especially food, medicinal and artisanal uses, among others.

Considering the seven actions for the development of silviculture and genetic improvement of native species, we prospected different stakeholders that could participate in developing and carrying out the TAP activities.

There are many educational and research institutions located in the Amazon, Atlantic Forest, Cerrado and Caatinga biomes, and given the quantity and diversity of expertise, there are many potential partners. As it is a highly complex plan with a broad geographical scope, partnerships with these institutions, and the involvement of the public and private sectors, will be required to improve the technical, scientific and logistical support needed to execute this TAP.

We can highlight some of the potential stakeholders and their missions that could support the implementation of the TAP actions:

1. Mapa, especially with reference to specific sectors or commissions, could contribute to logistical support, sanitary issues of seeds and seedlings and inspections for quality control of the above;

2. The MCTI is a potential partner with its *Regenera Brasil* initiative (created by MCTI Ordinance No. 3.206/2020) for scientific research, technological development and innovation to develop guidelines for the recovery of Brazilian native ecosystems. *Regenera Brasil* has three pilot projects in partnership with research units linked to the MCTI: two in the Amazon in partnership with the National Amazon Research Institute (Inpa) and the *Museu Paraense Emílio Goeldi* museum (MPEG); and one in the Atlantic Forest in partnership with the National Institute of the Atlantic Forest (Inma) (BRASIL, 2020);

3. Educational and research institutions, such asuniversities involved in multidisciplinary areas generating economic, social and environmental knowledge in the biomes. Additionally, Embrapa, with its scientific and technological forestry development activities in Brazil, is a potential partner, as well as Inpa, which has extensive projects and experience in the Amazon;

4. The MMA and partner organizations have carried out important work on native plants of the Brazilian flora: "Plants for the future - North, Northeast, Midwest and South regions." This research characterizes the uses of different species in the biomes considered in the TAP (CORADIN; CAMILLO; PAREYN, 2018);

5. Vale's *Reserva Natural Vale* [Vale Nature Reserve], located in the state of Espírito Santo, carries out important research on forest development in the Atlantic Forest biome;

6. Sebrae, a private, non-profit entity that stimulates entrepreneurship and competitiveness among micro and small enterprises is also a potential partner.

The TAP could be coordinated by Mapa and the MCTI, with Embrapa as the main technical partner responsible for the technical coordination of actions and activities. The MMA could also be part of the TAP Technical Advisory Committee, in conjunction with the institutions mentioned above. Research and teaching institutions located in the biomes could act as technical partners and disseminate the TAP results. Finally, a permanent team should be contracted to coordinate the execution of activities and report directly to the coordinating institutions.

Table 105 – Main stakeholders to involve in implementing the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
MCTI	The MCTI is involved in the following areas: national telecommunications policy, scientific and technological research, information technology and automation, among others. It could be responsible for coordinating the implementation of the TAP in view of the alignment between the TAP goals and the *Regenera Brasil* initiative.
Mapa	Mapa is responsible for the management of public policies to promote agriculture and agribusiness and for the regulation and standardization of services in the sector. Under its management, it seeks to integrate the marketing, technological, scientific, environmental and organizational aspects of the productive sector, as well as the supply, storage and transportation of crops and the management of agribusiness economic and financial policy. It could act in the coordination of the TAP.
Embrapa	Embrapa provides R&D and innovation solutions for the sustainability of agriculture for the benefit of Brazilian society. It could act as a partner in the technical coordination of TAP actions.
MMA	The MMA is responsible for: a) national policies for the environment and water resources; b) policies for the preservation, conservation and sustainable use of ecosystems and biodiversity and forests; c) proposing strategies, mechanisms and economic and social instruments to improve environmental quality and the sustainable use of natural resources; d) policies for the integration of the environment and production; e) environmental policies and programs for the Amazônia Legal region (designated Amazon zone); and f) ecological-economic zoning. It could be on the TAP Technical Advisory Committee.
Educational and research institutions located in the Amazon, Cerrado, Atlantic Forest and Caatinga biomes	They could act as technical partners in sub-activities 1.1 to 1.4; 2.2 and 2.3; 3.1 and 3.2; 4.1 to 4.3; 5.1 to 5.3; 6.1 to 6.4; and be dissemination agents and training target groups in sub-activities 7.1 to 7.3.
ME	The Ministry of Economy (ME) is responsible for the formulation and execution of the national economic policy and the financial administration of the State. It could support the TAP financing process.
BNDES	Main Federal Government instrument for long-term financing and investments in all segments of the Brazilian economy. It could finance TAP actions.
Finep	The Financier of Studies and Projects (Finep) promotes science, technology and innovation in companies, universities, technological institutes and other public and private institutions. It participates throughout the innovation chain, focusing on strategic, structural and impact actions for the sustainable development of Brazil. It could finance TAP activities.
CNPq	CNPq promotes and fosters scientific and technological development in Brazil and contributes to the formulation of national science and technology policies. It could finance TAP activities.
Sebrae	Sebrae is a private entity that fosters entrepreneurship and the competitiveness and sustainability of micro and small enterprises in Brazil. It could act as a technical partner in the execution of sub-activities 2.1 and 6.3.

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STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Senar	The mission of the National Rural Training Service (Senar) is to "provide professional education, technical assistance and social development activities, contributing to improving the development of sustainable production, competitiveness and social advances in the field. Among its actions, are: rural professional training, technical assistance and social development" (CNA, [sd] b). It could act as a partner for the execution of sub-activities 7.2 and 7.3.
Emater	In general, Technical Assistance and Rural Extension Companies (Emater) have the mission of "promoting sustainable rural development, coordinating, articulating and executing technical assistance and rural extension for the benefit of society" (EMATER-PR, [sd]). Emater companies could be responsible for the development of sub-activities 7.1 and 7.3.
Associations, foundations, cooperatives and companies in the sector	They could provide institutional support for the implementation of project activities, as well as being the target group of TAP dissemination and training actions.

Source: the author.

Schedule of actions and activities

The time frame for implementing the TAP is eight and a half years, a period believed adequate and sufficient for the financial and technical preparation and implementation of the seven TAP actions and associated activities. Within this time frame, we also intend to process the collection of growth data for the elaboration of growth and production prognosis models and validate hypotheses related to silviculture development processes and genetic improvement programs.

It should be noted that sub-activity 1.1, which involves an analysis of current knowledge on the technological properties and previous studies on the use of juvenile woods to select ten target species for study in the Amazon, Cerrado, Atlantic Forest and Caatinga biomes, is the only activity conducted in the first semester, since the other activities depend on its results.

In general, the sub-activities for technological studies of wood (1.2, 1.3 and 1.4) and seed and seedling production technology (4.1, 4.2 and 4.3) precede the genetic improvement sub-activities (2.1, 2.2, 2.3, 3.1 and 3.2). With respect to numeration of Action 4 activities, you will notice that there is an inversion in relation to Action 2 and 3 activities. This inversion is necessary, considering that sub-activity 2.2 (selection of populations and matrices within populations for the implementation of the combined provenance-progeny tests) is a genetic improvement action that takes precedence over the activities of Action 4.

Table 106 – TAP implementation schedule

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
1.1	■																	
1.2		■	■	■														
1.3			■	■														
1.4					■													
2.1					■													
2.2		■	■															
2.3				■	■		■		■		■		■		■		■	
3.1					■	■												
3.2							■		■		■		■		■		■	
4.1		■	■															
4.2		■	■	■														
4.3			■	■	■													
5.1						■	■			■	■			■	■			
5.2								■	■			■	■			■	■	
5.3									■		■		■		■		■	
6.1		■																
6.2		■	■	■														
6.3								■										
6.4				■	■	■	■	■	■	■	■	■	■	■	■	■	■	
7.1						■	■	■	■	■	■	■	■	■	■	■	■	
7.2							■	■	■	■	■	■	■	■	■	■	■	
7.3															■	■	■	

Source: the author.

10.5. TAP implementation costs and financing options

The total cost of the Plan was estimated at approximately BRL16.3 million. Among all the actions and activities, the implementation of Action 2, the most capital-intensive, accounts for approximately 29% of the total budget.

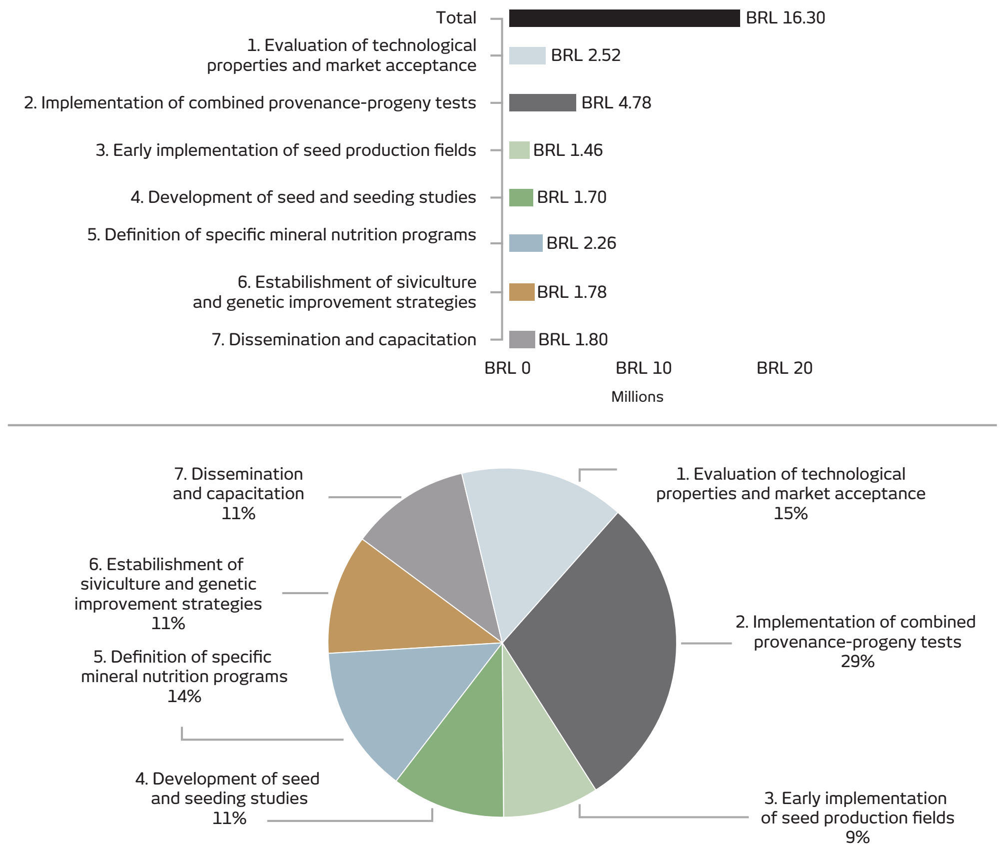

Figure 25 – Total cost per action, in millions of BRL and as a percentage, for the silviculture and genetic improvement of native species TAP

Source: the author.

With respect to potential sources of financing for the activities, and with a view to results and a focus on research and development, we determined the typical means of financing would be non-repayable loans and technical assistance. Financing is accessible for state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and in the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b).

10.6 Risk and contingency plan

We analyzed the potential risks involved to implement the TAP activities. The following risk categories were considered: political, institutional, organizational, technical and cost risks. They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs). Finally, contingency actions were proposed to mitigate these risks.

Of the 21 activities, 11 (52%) were considered low risk, eight (38%) medium risk and two (9%) high risk. Special attention should be paid to sub-activity 2.3 for the implantation of genetic tests in four different environmental zones, considering the edaphic and climatic characteristics prevalent in the Amazon, Cerrado, Atlantic Forest and Caatinga biomes, and to sub-activity 3.1 for the implementation of 40 untested seed production plantations for ten species from four biomes. In both activities, the high risks arise from the fact that these implementations, with the goal of reducing costs, must be maintained over a long period of time. Depending on the species, this period can be dozens of years and involve the use of public or private land (in partnerships) that is subject to changes (for example, changing ownership through inheritance or sale or re-designation of public land use).

Table 107 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1 Analysis of the current state of knowledge on the technological properties and previous studies on the use of juvenile woods to define ten target species for study, considering the Amazon, Cerrado, Atlantic Forest and Caatinga biomes	Technical risk and organizational risk	Analysis of the current knowledge and previous studies on the properties of juvenile wood of some tree species, per study biome, and their respective uses can be a complex activity due to the lack of data in the literature. Lack of coordination in the activity.	Low	The coordinator responsible for the activity, per biome, should seek complementary data from teaching and research institutions that work in the wood science and technology sector. Additional data can also be obtained from current research projects in the field, such as: Embrapa (several units), the Vale Forest Reserve in the state of ES, the Instituto Florestal de São Paulo etc. Carpentry professionals are another source of data on the uses of juvenile wood. Finally, the results should be validated by specialists in a meeting.

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continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.2 Evaluate the chemical, anatomical, physical and mechanical properties of juvenile woods to adapt them for industrial, commercial and other uses	Technical risk and organizational risk	Some species that stand out in relation to the use of juvenile wood may not be available for traditional sampling if the specimens are being studied for silviculture development, genetic improvement or forest management in the field. Testing delays may occur, as well as a lack of coordination for the activity.	Low	The coordinator of this activity, per biome, should locate young uncultivated specimens in natural forest conditions. The sampling of the wood produced from these specimens should be carried out considering the stage of their formation, which can be estimated by dendrochronology or microscopically by observing the radial variations in the anatomical structures of the wood. Establish contract deadlines for testing.
1.3 Build 60 demonstration units for the artisanal production of decorative objects; furniture industry; and construction industry using juvenile wood from the target species	Technical risk and organizational risk	Some species that stand out in relation to the use of juvenile wood may not be available to obtain the wood required for the demonstration units, especially if these specimens, due to their growth and shape, are being studied for silviculture development, genetic improvement or forest management in the field. Lack of supervision in the demonstration units. Delays in activities.	Medium	The coordinator of this activity should ensure young uncultivated specimens in natural forest conditions are selected in each biome. The juvenile wood should come from specimens with growth at DBH and trunk shape suitable for the demonstration units. Before cutting the localized specimens, it is necessary to conduct studies to assess the age of each specimen (as mentioned in sub-activity 1.2). However, in this case, the studies should be on samples obtained with an auger. Establish penalties for non-compliance with deadlines in third-party service contracts.

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.4 Conduct market research to assess the degree of acceptance of demonstration units (sub-activity 1.3) for the use of juvenile wood and characterize the technological innovation	Technical risk and organizational risk	Market research companies have no experience in assessing the acceptance of wood and non-wood products given the pioneering nature of the project.	Medium	Look for market research companies that have experience in conducting wood market studies or, failing that, companies specialized in the market for products with innovative technology. Finally, the activity coordinator should supervise the market study.
2.1 Estimate the economic values of wood and non-wood products in the domestic and international markets	Technical risk and organizational risk	It may be difficult to estimate market values for non-wood products, especially when it comes to art objects, such as handicrafts. There may also be difficulties in assessing the value of objects with innovative content. Lack of coordination and not achieving the objectives of the activity.	Low	Look for market research companies with experience in conducting studies on the commercialization of artistic works or with experience in the market for products with innovative technology. A coordinator should select the company and supervise the research.
2.2 Select populations (origins) and matrices within populations for the implementation of combined provenance-progeny tests	Technical risk and organizational risk	Several tree species have non-annual flowering and fruiting phenology and, in other cases, certain populations and matrices suffer intense seed predation by animals. Lack of coordination and qualified labor to conduct the analysis.	Medium	Lack of seeds at collection time of may require substituting the species. In this case, it should be replaced by one on the list of species with known (or potential) uses, even if the studies in Action 1 have to be redone. Contract a technical team, including a coordinator, with expertise in the area.

continues

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
2.3 Carry out the tests in four different environmental zones, considering the edaphic and climatic characteristics prevalent in the Amazon, Cerrado, Atlantic Forest and Caatinga biomes	Technical risk, organizational risk and institutional risk	The implementation of genetic tests in the field depends on partnerships with public or private institutions so that areas of land are available for long periods. Delays and inconsistencies in results.	High	When preparing projects, partnerships for the concession of experimental areas should be made official and regulated in contracts, since public areas can be used for other purposes and private areas can be transferred to other owners, either through sale or inheritance. In addition, it is necessary to supervise the tests and ensure the delivery of results.
3.1 In parallel with the combined tests (Action 2), implement 40 untested seed production plantations using seedlings of clonal or seminal origin from each sampled matrix	Technical risk, organizational risk and political risk	The implementation of seed production units in the field depends on partnerships with public or private institutions so that areas of land are available for long periods. Lack of coordination and delays in implementing plantations.	High	When preparing projects, partnerships for the concession of areas for the implementation of seed production units should be made official and regulated in contracts, since public areas can be used for other purposes and private areas can be transferred to other owners, either through sale or inheritance. Supervise activities and ensure compliance with contract deadlines.
3.2 Thinning of progeny trees that fail the provenance-progeny tests (Action 2) to transform the untested seed production plantations into tested ones using annual data obtained in the tests	Technical risk and organizational risk	Both genetic tests and plantations for future seed production can suffer anthropic damage or biotic and abiotic stresses. Delays in Action 2.	Medium	Avoid experimental areas very close to communities, establish the four experimental areas per biome (as planned) and carry out monitoring of tests and plantations every six months, especially for the maintenance of firebreaks and monitoring pests and diseases. Ensure delivery and centralized coordination in Actions 2 and 3.

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continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
4.1 Establish protocols for the collection, transportation, processing and storage of seeds for each of the selected species	Technical risk and organizational risk	Some tree species have seeds that suffer during transport, processing and especially storage, compromising their seedling production capacities to produce the desired quantities. Lack of supervision in the activity.	Low	In the species selection process, in addition to studies on the use of wood and non-wood products and silviculture behavior, the standard protocol for maintaining the viability of the seeds of the selected species should be followed as closely as possible. The activity should be coordinated by a specialist in the area.
4.2 Develop or adapt protocols to control seed quality through physiological and biochemical studies, especially in relation to storage longevity, dormancy, germination and plant health	Technical risk	Physiological and biochemical studies of seeds are indispensable for the development or adaptation of protocols for storage and breaking seed dormancy. Some selected species may present inconclusive results, making it difficult to adopt appropriate techniques to maintain the seed germination rates and seedling health at acceptable levels.	Low	Collect as many seeds as possible from matrices. The marked and geographically referenced matrices that have low seed production at the time of seed harvest should be replaced by others within the population.
4.3 Develop or adapt protocols for quality control of seedlings in the nursery and trees in the field through morphological, physiological and biochemical studies, especially with regard to tolerance / resistance / resilience to biotic and abiotic stresses	Technical risk and cost risk	Generally, biotic and abiotic stresses are unpredictable, especially in terms of intensity. This may require the production of more seedlings or replanting in the field.	Medium	Control the agents that cause biotic and abiotic stresses. In the case of the former, spray to prevent or control pests and diseases, and for the latter, acclimate the seedlings in the nursery at the proper time and control operations during and after planting in the field. Finally, ensure contingency resources for the activity.

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continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
5.1 Assess the mineral needs (macro- and micro-nutrients) of each target species in the seedling phase in the nursery and trees in the field	Technical risk and organizational risk	Inconclusive results with some species can lead to erroneous estimates of nutritional needs, resulting a reduction in the development of seedlings or trees in the field due to nutritional deficiencies or phytotoxicity due to an excess of some mineral elements. Lack of supervision in the activity.	Medium	Control the schedule and quantity of fertilizer applications in the nursery and in the field. Monitor and control nutrition using symptom assessments or leaf analysis. Ensure a specialist supervises the activity.
5.2 Develop specific mineral nutrition programs for each of the ten target species		Lack of knowledge of mineral nutrient needs (sub-activity 5.1) may hinder the development of adequate mineral nutrition programs. The lack of joint supervision with sub-activity 5.1 would also be detrimental.	Low	Improve methods for monitoring and controlling nutritional deficiencies through periodic soil analysis and deficiency symptoms (sub-activity 5.3). Intervene with complementary fertilizers at the optimal time to ensure the healthy development of seedlings and trees. Contract a supervisor for these activities.
5.3 Define a methodology for diagnosing nutritional deficiencies using visual analysis of seedling organs in the nursery and trees in the field		Poor deficiency diagnoses could lead to the inadequate application of nutrients, compromising the development of seedlings and trees. Lack of validation of the methodology. Lack of supervision in the activity.	Low	The diagnosis of nutrient deficiency or excess by analysis of symptoms in plant organs should be carried out as quickly and accurately as possible. To do this, prepare booklets with descriptions and photos of the symptoms associated with the nutrition deficiency or excess. A specialist should validate the methodology. Ensure supervision of the deliveries of activities.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
6.1 Evaluate the applicability of edaphic-climatic zoning for the cultivation of traditional tree species for reforestation in Brazil.	Technical risk and institutional risk	Edaphic-climatic zoning for the cultivation of another plant species may have interpretation errors. This can lead to selecting inappropriate areas.	Medium	Adapt the zoning for the cultivation of traditional tree species for reforestation in Brazil. If not possible, develop specific zoning for the species and biome.
6.2 Test cloning by mini-cutting and tissue culture adhering to protocols developed by research institutions for the cultivation of traditional tree species		The cloning process for some tree species, especially mini-cutting, is well known. However, the problems in using this technique in clonal forestry can have negative consequences given the lack of long-term results.	Low	In this activity, the objective is only to conduct tests with experimental evaluation of seedlings in the nursery. The adoption of this technique for the development of clonal silviculture can only be done with long-term studies. If any species adapts well to the technique, it should be minimally cultivated in field conditions for future evaluations. Thus, a TCA should be established with an institution with expertise in the area to carry out long-term studies (post-project).
6.3 Develop or adapt market research methodologies for wood and non-wood products using the native tree species in this project	Technical risk	The market research for wood and derivatives of some tree species is relatively well known. However, adapting the methodologies of these studies may lead to errors in results.	Low	Contract companies specialized in market identification and analysis, especially the international market, for wood and non-wood products. Validate the methodology developed or adapted with specialists.
6.4 Evaluate the applicability of the knowledge generated in projects for monitoring and controlling pests and diseases of traditional tree species cultivated in Brazil	Technical risk	Pest and disease monitoring programs are laborious and time-consuming to prepare. Collecting existing data is necessary, and this can be very time-consuming.	Low	Identify the main pests and diseases of each selected species and conduct research in the literature, especially on reproductive biology and behavioral ecology to create an integrated pest and disease management plan for each species.

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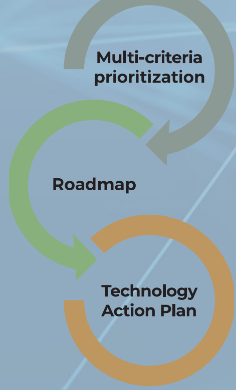
continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
7.1 Develop, implement and conduct small-scale crop testing aimed at demonstrating silviculture techniques, processing wood and non-wood products and disseminate productivity results and cost, production and profitability data	Technical risk and organizational risk	Like genetic tests and seed production plantations, demonstration cultivation tests can suffer anthropic damage or biotic and abiotic stresses.	Medium	Avoid areas for pilot-scale plantations that are very close to communities. Implement at least four demonstration areas per biome. Carry out bi-yearly monitoring of firebreaks and pests and disease.
7.2 Develop an online platform to disseminate the techniques, products and results of the TAP actions and activities	Technical risk	Potential communication risks due to the lack of reliable media and conflicts over content and data security that can affect both external and internal platform communication.	Low	Identify and remedy communication problems as soon as they are detected. Ensure the best communication practices, channels and protocols for sharing information.
7.3. Elaborate and disseminate guidelines for the development of elective courses and the provision of distance education courses in silviculture technologies and genetic improvement of native species	Organizational risk	The development of courses and curricula for undergraduate and graduate courses and distance education involves legal procedures with course coordinators and higher levels at educational institutions.	Low	When preparing projects, obtain the consent of the official responsible for the curricula of the educational institution and for the provision of distance learning courses.

Source: the author.

11.

Technology Action Plan **for Silviculture with Mixed Planting for Restoration**



11. TECHNOLOGY ACTION PLAN FOR SILVICULTURE WITH MIXED PLANTING FOR RESTORATION

11.1. Definition of technology

The TAP proposes the use of mixed plantation silviculture using exotic and native species in protected areas designated Legal Reserves (*Reserva Legal* - RL) or Permanent Protection Areas (*Area de Proteção Permanente* - APP) as an alternative to the Degraded Areas Recovery Plan (*Plano de Recuperação de Áreas Degradadas - Prad*) under the Brazilian Forest Code. The implementation of this technology is aimed at developing plantations for environmental restoration and providing socioeconomic benefits for landowners required to make changes to comply with the Environmental Regularization Program (PRA).

This approach recognizes the use of tree species as the most appropriate option for environmental restoration since it also provides potential benefits from the production and commercialization of forest-related products for subsistence and income generation on properties. The combination of agriculture and livestock in mixed systems with silviculure (ICLFS) represents a more flexible option with additional benefits.

Although the main objective in implementing the technology is environmental restoration, allowing owners to use their properties for the production and commercialization of different kinds of products provides an opportunity for landowners to become actively involved in restoration and conservation actions. In addition, this involvement can provide employment and income on a regional basis, contributing to socioeconomic development in regions with low HDIs. The use of this technology by producers for the production and commercialization of products should meet criteria for the suitability of areas (for example, edaphoclimatic factors) and landowners for these activities, in addition to regional aspects and market potential. In addition to the benefits for producers, the expansion mixed plantation silviculture for restoration has significant potential for mitigating climate change by sequestering CO_2 in biomass, in addition to potential reductions in the use of fertilizers.

11.2 Scope and goals

Generally speaking, in mixed plantations, exotic and native trees are planted in an integrated manner with agricultural and livestock production with potential for generating economic products for different purposes. It is an option that ensures better soil use, reversing natural resource degradation processes while increasing the supply of wood, food and environmental services (RIBASKI, 2019).

However, knowledge is still lacking with respect to the ecological and socioeconomic efficiency of mixed planting silviculture systems. There is no explicit definition of "efficient systems," but these systems are a viable option for better soil use, reversing natural resource degradation processes while increasing the supply of wood, food and environmental services. Due to their multiple uses, these integrated production systems, or Integrated Crop-Livestock-Forest Systems (ICLFS), constitute viable economic, ecological and social options for strengthening agriculture. They also offer a number of benefits, such as increased production, greater employment and income for rural producers and sustainable development (RIBASKI, 2019). When these systems are able to reconcile conservation and production activities, measured with ecological and economic indicators, they can be considered efficient.

Another important goal of this technology is the demonstration and dissemination of the potential of mixed plantations for restoration under the Brazilian Forest Code (Federal Law nº 12.651 / 2012). These systems offer a cross-sectoral approach that can reconcile regulatory, economic and ecological needs (an essential factor for developing the value chain of this technology). However, an effort is required to generate refined data, aligned with the state PRA regulations and other relevant legislation and regulations. This data needs to be validated in the field, especially taking into account the diversity of Brazilian biomes and their different edaphoclimatic characteristics.

To this end, the scope of the TAP is to evaluate the ecological and economic potential of mixed plantation silviculture for restoration through actions to supply and expand the forestry chain under current forest regulations.

Naturally, for these systems to be scalable, they require the support of adequate infrastructure and logistics, among others. Thus, the goal of the TAP is the creation or improvement of policies for mixed plantation restoration, as well as the validation, in the field, of efficient mixed systems that satisfy ecological, economic and regulatory criteria, aimed at restoring different biomes and protected areas in Brazil by 2030.

Table 108 – TAP scope and goals

SCOPE	GOALS
Assess the ecological and economic potential of mixed plantation silviculture for restoration through actions to supply and expand the forest chain under current forest regulations.	The creation or improvement of policies for mixed plantation restoration, as well as the validation, in the field, of efficient mixed systems that satisfy ecological, economic and regulatory criteria, aimed at restoring different biomes and protected areas in Brazil by 2030.

Source: the author.

11.3. Actions and activities

Critical gaps and barriers and means to overcome them

In the initial stage of the project, we identified 15 significant barriers to the development of mixed plantation silviculture for restoration. Among them, we selected the most critical to the diffusion of the technology, considering the 2030 implementation target.

We identified nine critical barriers to the development and implementation of mixed plantation silviculture for restoration. Four are regulatory, two are technological and scientific, one is associated with dissemination and training and, finally, two are physical barriers. To overcome these barriers, we propose to improve the institutional framework and validate mixed planting systems in the field that are ecologically and economically efficient, and that comply with regulations, for the purpose of restoring different biomes and protected areas in Brazil by 2030.

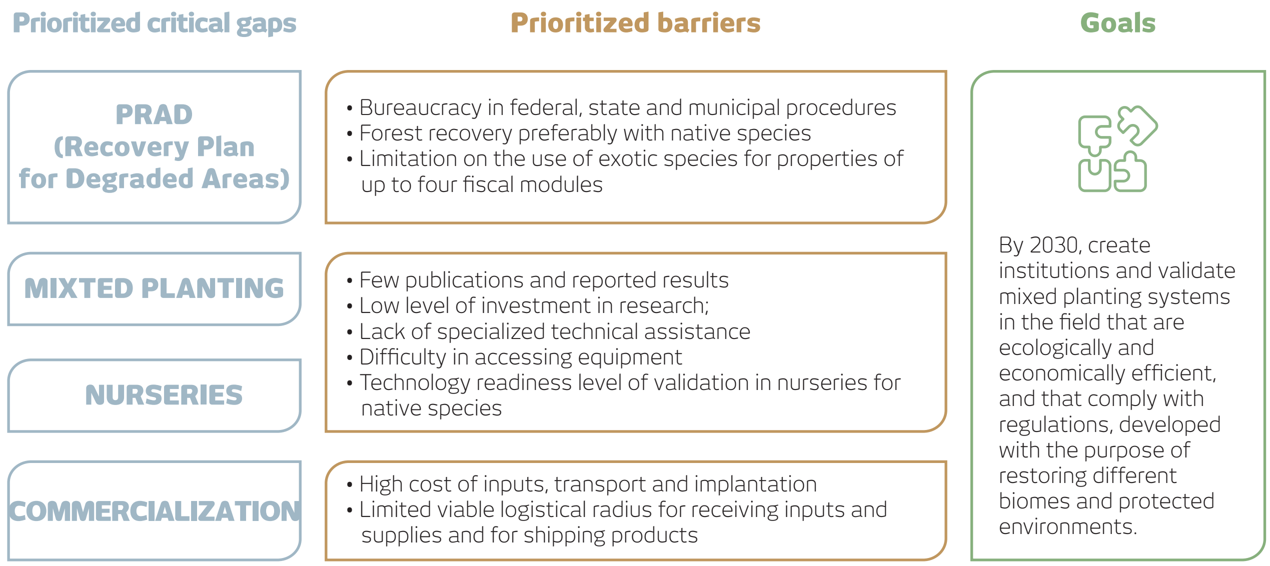


Figure 26 – Critical gaps and barriers and priority goals

Source: the author.

Actions and activities

The first necessary step is to propose or improve the regulatory and institutional framework and disseminate this information to the forestry sector. Following this, it is essential to survey and refine existing data on mixed planting and, when necessary, carry out new studies, taking into account the need to validate this data in the field. Finally, it is essential to disseminate information and practical and structural proposals that can improve the restoration chain. Each of the proposed actions is composed of a number of activities for the step-by-step execution of the TAP.

Action 1 and related activities

This action is directly related to the elaboration or improvement of regulatory and/or infra-legal instruments and their dissemination to all stakeholders involved in the restoration chain. To this end, we propose four activities that translate this objective into actions.

To provide some context, six Brazilian states (Alagoas, Amapá, Ceará, Rio Grande do Norte, Roraima and Sergipe) are in the preliminary phase of implementing the Brazilian Forest Code. The regulation of the Rural Environmental Registry (*Cadastro Ambiental Rural*) and the Environmental Regularization Program (PRA) is still in the draft phase, without major advances in its implementation (CHIAVARI; LOPES, 2019). Thus, the first activity involves holding workshops with different stakeholders to develop an instrument with adequate scope that satisfies the requirements of the regulation.

The second activity is aimed at Brazilian states that have already regulated their PRAs, but need to elaborate complementary norms to properly promote the environmental regularization of rural properties, as is the case in the states of Amazonas, Goiás, Paraná, Pernambuco, Santa Catarina and Tocantins. An example of these other regulations are the specific regulations for the implementation of agroforestry systems in Legal Reserves and Permanent Protection Areas.

Sub-activities 1.3 and 1.4 are related to dissemination in the field, as they seek to translate and communicate these regulatory instruments to all stakeholders in the restoration chain. Sub-activity 1.3 specifically seeks to disseminate the PRA and the instruments proposed/created in sub-activities 1.1 and 1.2. To assist in this dissemination process, the activity also involves the elaboration of non-legal instruments, such as operational technical manuals for restoration and booklets on the implementation of mixed plantations.

However, for this process to be efficient, it requires support or a schedule of activities in conjunction with Ater in a Network, as well as research on restoration for the different forest restoration stakeholders in the country. Sub-activity 1.4 is important for the effectiveness of the process. An important element is the institutionalization of the Network, which is why there is a budget for the elaboration of an Ordinance to create the Network.

Table 109 – Action 1 and related activities

ACTION 1 – ELABORATION, IMPROVEMENT AND INSTITUTIONAL DISSEMINATION OF REGULATORY, INFRA-LEGAL AND RESEARCH INSTRUMENTS	
Sub-activity 1.1	Map current best regulatory instruments and promote workshops and meetings with different stakeholders for the elaboration/implementation of PRA regulations
Sub-activity 1.2	Assess the need for other instruments to guarantee legal security for properties, citing specific regulations for agroforestry systems
Sub-activity 1.3	Elaborate non-legal instruments, booklets and web media to disseminate the proposals in previous activities to the different stakeholders in the chain
Sub-activity 1.4	Elaborate and implement a joint and networked schedule of Ater training activities and research involving rural assistance and extension agencies and research institutes and universities

Source: the author.

Action 2 and related activities

The goal of Action 2 is the validation of mixed planting systems in the field to demonstrate their ecological and economic efficiency. These activities require effort from the project's technical team to prepare public notices and contract partners to carry out the activities.

Sub-activity 2.1 initially involves the mapping of target areas for restoration. Given that this geographical area is considerable, it should prioritize these areas using criteria to be defined in the activity.

Sub-activity 2.2 underscores the need to create a solid scientific base for these systems, including taking advantage of the expertise of other initiatives in areas where knowledge is lacking. To this end, it is necessary to carry out research to identify the best species to be planted together, taking into account edaphoclimatic characteristics.

Another important aspect is the temporality of restoration and sensitivity to external ecological and man-made factors. Thus, standardized methodologies and protocols are essential for measuring the progress of restoration with mixed plantations, observing the diversity of biomes, phytophysiognomies and the differences between protected areas. This is the goal of sub-activity 2.3, which specifically proposes technical-scientific studies and field research to develop ecological indicators and reference values. Some Brazilian states are pioneers in this initiative, such as São Paulo, Mato Grosso and the Federal District, and already have infra-legal instruments for this purpose.

Finally, sub-activity 2.4 seeks to validate the research and studies carried out in sub-activities 2.2 and 2.3 with other specialists in these areas and, especially, rural landowners who will implement these systems and monitor their progress. This validation can lead to a calibration of these systems and a repetition of sub-activities 2.2 and 2.3 in view of the environmental heterogeneity in Brazil and the dynamics of land use.

Table 110 – Action 2 and related activities

ACTION 2 – VALIDATION IN THE FIELD OF MIXED SYSTEMS THAT ARE ECOLOGICALLY AND ECONOMICALLY EFFICIENT AND COMPLIANT WITH REGULATIONS FOR DIFFERENT BIOMES	
Sub-activity 2.1	Map priority restoration areas with geoprocessing and remote sensing tools based on ecological and economic criteria
Sub-activity 2.2	Map existing initiatives and carry out studies and field research to fill knowledge gaps to identify the best species to be planted together and best suited to each environment for restoration, considering edaphoclimatic characteristics
Sub-activity 2.3	Studies and field research for developing ecological indicators and reference values to measure the progress of restoration in each of the states and biomes
Sub-activity 2.4	Presentation, validation and revision of studies in workshops with farmers, producers and other specialists

Source: the author.

Action 3 and related activities

After the validation in the field of the regulatory and scientific activities, action is required to foster the development of the mixed plantation value chain. This action aims to test institutional arrangements and optimize resources, directing them to overcome the main bottlenecks. Sub-activity 3.1 seeks to identify bottlenecks and opportunities in the forest chains in different biomes. Sub-activity 3.2 involves the implementation of 12 pilot mixed planting system demonstrating units for restoration to test productive arrangements, taking into account the complexity and need to monitor restoration. The demonstration units will also serve as models or a "control group" for comparisons with other initiatives and studies.

An important factor for the development of the chain is improving infrastructure, ensuring easy access to resources and inputs and the commercialization of products from these systems. Sub-activity 3.3 focuses on a fundamental resource: seedlings. To this end, it is necessary to implement forestry nurseries and protocols for seedling production.

Sub-activity 3.4 involves the creation of a platform to disseminate the benefits of mixed planting systems for restoration by sharing articles, maps and regulatory instruments developed by universities and research centers, private initiatives and state and municipal agencies, among others. Moreover, it is a strategy to move products from these systems and improve the economic efficiency of the chain. The platform should be a link between producers and consumers, fostering commercialization and optimizing logistics. The platform is also important for input and machinery suppliers as it can help to minimize costs and disseminate innovation.

Finally, sub-activity 3.5 involves training human resources and the elaboration and dissemination of guidelines for the development of elective courses on mixed plantation silviculture technologies for higher education degrees in Exact and Earth Sciences and Engineering. It is important to note that this activity is also related to Action 2, specifically sub-activities 2.2 and 2.3, and can use their results.

Table 111 – Action 3 and related activities

ACTION 3 – FOSTER THE DEVELOPMENT OF MIXED PLANTATION SILVICULTURE FOR RESTORATION TO MINIMIZE COSTS AND IMPROVE PRODUCTION EFFICIENCY	
Sub-activity 3.1	Map the forestry chains in each Brazilian biome and identify the main bottlenecks and ecological and economic opportunities
Sub-activity 3.2	Implement and monitor 12 mixed plantation demonstration pilot units for restoration
Sub-activity 3.3	Analysis and implementation of nurseries to supply the forestry restoration chain
Sub-activity 3.4	Development of a platform for the dissemination of benefits and tools to foster mixed plantation silviculture in the restoration chain
Sub-activity 3.5	Elaboration and dissemination of guidelines and education for the development of elective courses on mixed plantation silviculture technologies for higher education degrees in Earth and Exact Sciences and Engineering

Source: the author.

11.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

The identification of the key stakeholders for the implementation of the actions is essential to expand and diffuse mixed plantation silviculture for restoration. As the technology has synergy with the activities of numerous organizations, there is ample stakeholder diversity. The mapping of local stakeholders and networks is an essential step for the success and expansion the restoration chain, aimed at valuing and potentializing current initiatives and links, as well as overcoming bottlenecks and fostering cooperation. Thus, we identified stakeholders with recognized expertise in the technology with missions that are aligned with the TAP goals.

We identified a number of potential stakeholders that could be important for the successful implementation of the technology. We can highlight the following institutions: Mapa, Embrapa, MCTI and MMA. Mapa could assume the general coordination of the actions due to its expertise, including some of its secretariats and specific sectors, such as the Seedling Quality Control and Forestry Nursery Inspection Sector and Ceplac, which have extensive expertise in agroforestry systems. Given its technical-scientific expertise, Embrapa could be the main technical partner for carrying out activities. The MCTI could technically coordinate Action 2, in view of the alignment of the TAP scope and goals with the *Regenera Brasil* Initiative (created by Ordinance No. 3,206 / 2020) (BRASIL, 2020). Finally, the MMA could act in the technical coordination of sub-activities 1.1 and 1.2.

Table 112 – Main stakeholders to involve in implementing the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Mapa	Mapa is responsible for the management of public policies to promote agriculture and agribusiness and for the regulation and standardization of services in the sector. Under its management, it seeks to integrate the marketing, technological, scientific, environmental and organizational aspects of the productive sector, as well as the supply, storage and transportation of crops and the management of agribusiness economic and financial policy. It could coordinate the project and act in the technical coordination of sub-activities 1.1, 1.2, 3.1, 3.4 and 3.5.
MMA	The MMA is responsible for: a) national policies for the environment and water resources; b) policies for the preservation, conservation and sustainable use of ecosystems and biodiversity and forests; c) proposing strategies, mechanisms and economic and social instruments to improve environmental quality and the sustainable use of natural resources; d) policies for the integration of the environment and production; e) environmental policies and programs. It could work in partnership with MAPA in the technical coordination of sub-activities 1.1 and 1.2.
Embrapa	Embrapa provides R&D and innovation solutions for the sustainability of agriculture for the benefit of Brazilian society. It could act as the main technical partner in the execution of different sub-activities, including 1.1 to 1.4; 2.1 to 2.4; 3.2 and 3.3.
MCTI	The MCTI could assume the role of technical coordination of Action 2 in view of the alignment between the *Regenera Brasil* initiative and the TAP scope and goals.
SFB	The Brazilian Forest Service (SFB) is responsible for the management of public forests (forest registration and concession, management and monitoring) and for sustainable forestry development (forest inventory, research and development and the Rural Environmental Registry). It could act as a partner on the Technical Committee for the supervision of sub-activities 1.1, 1.2. 2.4, 3.1 and 3.3.

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STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Incra	The priority mission of the National Institute for Colonization and Agrarian Reform (Incra), a federal authority, is to implement agrarian reform and carry out national land planning. Incra is responsible for land tenure regularization at the federal level. Land regularization is a requisite or prior step to environmental regularization. Incra could have important institutional participation on the Technical Committee for sub-activities 1.1, 1.2 and 2.4.
Brazilian state Environment and Agriculture Secretariats	They could act as sub-national partners and provide institutional support for the validation of sub-activities 1.1, 1.2, 2.4 and 3.3.
State Forestry Institutes	The State Forestry Institutes are closely linked to the forestry chain. In their respective states, they have large databases of forestry mapping and some components of the forestry chain. Hence, the need for their participation in the creation of regulatory instruments in sub-activities 1.1 and 1.2 and in the analysis and implementation of forestry nurseries (sub-activity 3.3). Ideally, they would be part of the Technical Committee.
Emater	Technical Assistance and Rural Extension Companies (Emater) could act as technical partners for the development of sub-activities 1.1 to 1.4; 2.1 to 2.4; and 3.2 to 3.4.
Inpe	The National Institute for Space Research (Inpe) is an internationally recognized federal institute in the areas of space and Earth sciences whose mission is to promote science and technology and provide specialized products and services for the benefit of Brazil. It could provide spatial data for sub-activities 2.1 and 3.1.
Sector confederations and bodies	They could provide institutional support for the execution of sub-activities 1.3 and 1.4, and be the target group of sub-activities 3.4 and 3.5.
Water management agencies	Water management agencies are decentralized executive units that support their respective Hydrographic Basin Committees, providing administrative, technical and economic support. The Hydrographic Basin Plans are important instruments for the management of water bodies and have a number of actions that are directly related to forest restoration. They could provide important support for the creation of regulatory instruments, specifically in sub-activities 1.1 and 1.2, and provide expertise for the analysis of the landscape.
NGOs	Target group of sub-activity 3.4.
Federal and state universities and their laboratories related to forestry	They could act as technical partners in sub-activities 1.1 to 1.4; 2.1 to 2.4; and 3.4 and 3.5.
Senar	The National Rural Training Service (Senar) provides services for rural professional training, technical assistance and social development. It could act in the TAP training and dissemination activities (sub-activities 1.3, 1.4 and 3.4).
Brazilian Ecological Restoration Society	The Brazilian Ecological Restoration Society cooperates with universities, research institutes, consulting companies, NGOs, rural extension and forestry organizations and the private sector, in addition to having a presence in all regions, biomes, ecosystems and among stakeholders in the restoration of ecosystems in Brazil. This organization involves a number of renowned forest restoration experts and could be of great value in Action 2, especially sub-activities 2.2, 2.3 and 2.4.

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STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Capes	The Coordination for the Improvement of Higher Education Personnel (Capes) plays a fundamental role in the expansion and support of specialized graduate studies (masters and doctorate degrees) in all Brazilian states. In addition, it supports basic education teacher training, expanding the scope of its actions in the training of qualified personnel in Brazil and abroad. It could promote TAP Actions 2 and 3.
CNPq	CNPq promotes and fosters scientific and technological development in Brazil and contributes to the formulation of national science and technology policies. It could promote TAP Actions 2 and 3.
ICMBio	The Chico Mendes Institute (ICMBio) could act as an institutional partner in sub-activity 3.1.
Ibama	The Brazilian Institute of Environment and Renewable Natural Resources (Ibama) could act as an institutional partner in sub-activity 3.1.
Funai	The National Indian Foundation (Funai) could act as an institutional partner in sub-activity 3.1.
IBGE	The IBGE could act as an institutional partner in sub-activity 3.1.
ME	The Ministry of Economy (ME) is responsible for the formulation and execution of the national economic policy and the financial administration of the State. It could mobilize resources for the execution of the TAP.
Febraban	The Brazilian Federation of Banks (Febraban) represents the banking sector and contributes to the economic, social and sustainable development of the country, promoting the continuous improvement of the financial system and its relations with society. It could provide institutional support for the mobilization of resources for the execution of sub-activity 3.2.
BNDES	Main Federal Government instrument for long-term financing and investments in all segments of the Brazilian economy. It could promote the implementation of the TAP.
Associations and cooperatives	Target group of sub-activity 3.4.

Source: the author.

Schedule of actions and activities

The time frame for implementing the Plan is eight and a half years. Notably, the actions do not follow a sequential schedule. Some activities take place concurrently: sub-activities 1.1, 2.1, 3.1 and 3.4 in the short term; 1.2, 1.3, 1.4, 2.3, 2.4 and 3.2 in the medium term; and 3.2, 3.4 and 3.5 in the long term. This allows technical-scientific knowledge and field activities to be linked to institutional and regulatory definitions. In addition, some actions may take advantage of (or benefit from) the results of other actions, such as sub-activities 3.1 and 3.3. Long-term activities are those that depend on multiple stakeholders or spheres of power, and that require a greater amount of external resources.

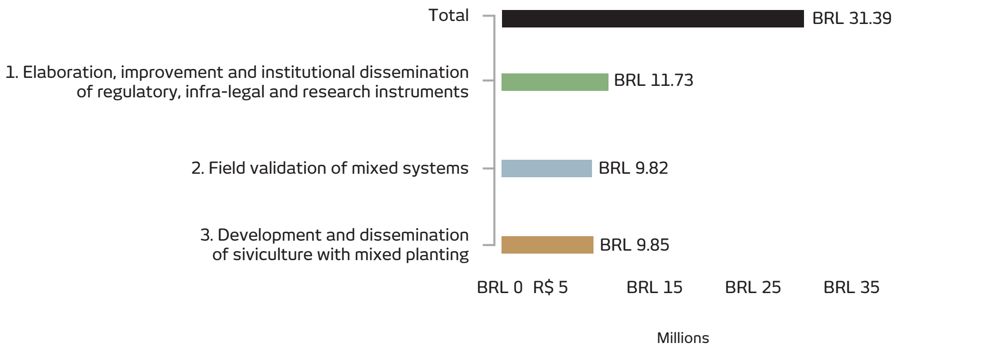
Table 113 – TAP implementation schedule

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
1.1	■	■	■	■	■													
1.2						■	■											
1.3								■	■	■	■							
1.4						■	■	■	■	■	■	■	■	■	■	■	■	
2.1	■	■																
2.2			■	■	■													
2.3						■	■	■										
2.4									■	■								
3.1	■	■																
3.2											■	■	■	■				
3.3	■	■	■	■														
3.4														■	■	■	■	
3.5															■	■	■	

Source: the author.

11.5. TAP implementation costs and financing options

The total cost to implement the TAP was estimated at BRL 31.4 million. This budget is distributed evenly over the three TAP actions. The activities that involve studies and infrastructure have the highest costs.



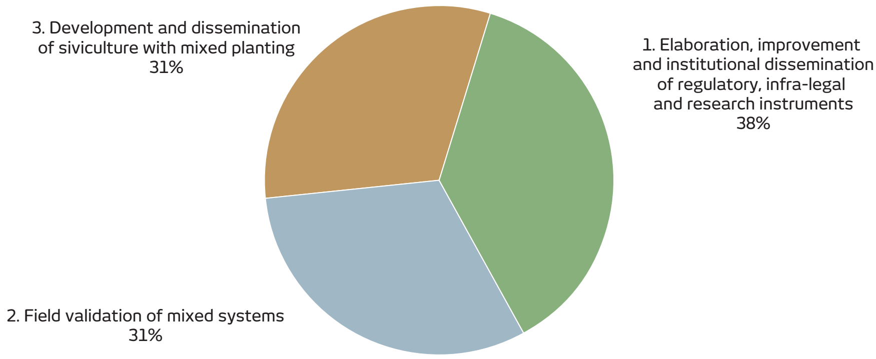


Figure 27 – Total cost per action, in millions of BRL and as a percentage, for the mixed planting silviculture for restoration TAP

Source: the author.

With respect to potential sources of financing for the activities, and with a view to results and a focus on research and development, we determined the typical means of financing would be non-repayable loans and technical assistance for Actions 1 and 2. Financing is accessible for state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives. In the case of Action 3, in view of the implementation of demonstration units, financing could come from payment for environmental services.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and in the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b).

11.6 Risk and contingency plan

The risks indicate areas that need attention when implementing the project and carrying out the activities. The contingency actions are of a preventive or corrective nature. We analyzed the potential risks according to the level of severity and consequences. The following risk categories were considered: political, institutional, organizational, technical and cost risks. They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs).

In general, the activities classified as medium risk are those that involve a large number of stakeholders with different expectations. This can lead to potential conflicts of interest and reduced engagement. The activities considered high risk involve the development of infrastructure and, therefore, require more resources, especially for long-term maintenance.

Table 114 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1 Map current best regulatory instruments and promote workshops and meetings with different stakeholders for the elaboration/ implementation of PRA regulations	Political risk, organizational risk, technical risk and institutional risk	Risk of conflicts of interest, due to participating organizations having different expectations for the activity. There is also the risk of lack of political-institutional commitment from participants, especially those in higher spheres of power, since the activity requires more intense engagement. Lack of technical coordination and qualified professionals to conduct the activity.	Medium	Map stakeholders, their history and current roles in the restoration chain. Map organizations that support farmers and invite them to the event. Ensure the participation of the highest levels of power in events through bilateral meetings to clearly present the objectives of the activity. Contract professionals with expertise in the area, including the technical coordinator of the activity. Establish contractual penalties for late delivery of results.
1.2 Assess the need for the creation of other instruments to guarantee legal security for properties, citing specific regulations for agroforestry systems			Medium	

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continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.3 Elaborate non-legal instruments and booklets and web media to disseminate the proposals in previous activities to the different stakeholders in the chain	Political risk, technical risk and institutional risk	Risk of conflicts of interest, due to participating organizations having different expectations for the activity. There is also the risk of lack of political-institutional commitment from participants, especially those in higher spheres of power, since such activity requires more intense engagement. Risk of delays in delivering the results of previous activities.	Low	Map stakeholders, their history and current roles in the restoration chain. Map organizations that support farmers and invite them to the event. Contract professionals with expertise in the area, including the technical coordinator of the activity. Ensure the results from the previous steps are available to the technical team.
1.4 Elaborate and implement a joint and networked schedule of Ater training activities and research involving rural assistance and extension agencies and research institutes and universities	Institutional risk, political risk and organizational risk	Risk of conflicts of interest, due to participating organizations having different expectations for the activity. Lack of interest in training activities. Lack of cooperation between stakeholders. Difficulty implementing Ater and Network research activities. Lack of Network institutionalization.	Medium	Based on secondary data, outline possible Ater topics that could be added to the Agenda to guarantee institutional support before the meeting with the stakeholders. Ensure comprehensive dissemination of activities using digital tools. Ensure stakeholder cooperation at national and sub-national levels for the institutionalization of the Network. Carry out a legal analysis for the Ordinance. Contract a permanent project team to institutionalize Network activities.

continues

continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
2.1 Mapping of priority restoration areas with geoprocessing and remote sensing tools based on ecological and economic criteria	Technical risk and organizational risk	Difficulty accessing details for mapping similar to that seen in the field. Difficulty contracting qualified labor. Lack of technical coordination. Delays in the delivery of results.	Low	Adopt and validate methodologies that can overcome the lack of detail. Ensure Network stakeholders share information and expertise and participate in the technical team. Contract a specialist to assume the role of technical coordination. Present work plan and schedule of sub-activities.
2.2 Map existing initiatives, and carry out studies and field research to fill knowledge gaps, to identify the best species to be planted together and best suited to each environment for restoration, considering edaphoclimatic characteristics 2.3 Studies and field research for developing ecological indicators and reference values to measure the progress of restoration in each of the states and biomes	Technical risk and organizational risk	Complexity of the study and access to data. Errors in the analysis of sub-activity 2.1 data resulting in the selection of inappropriate areas. Lack of coordination in the activity and difficulty contracting qualified labor. Delays in completing the activity.	Low	Contract research institutes with expertise in the area that use effective technologies and tools. Ensure sub-activity 2.1 results are validated. Establish contractual penalties for late deliveries.
2.4 Presentation, validation and revision of studies in workshops with farmers, producers and other specialists	Institutional risk and technical risk	Risk of conflicts of interest, due to participating organizations having different expectations for the activity. Engagement requires mobilization and social engagement techniques, especially for farmers and producers in this activity. Delays in the delivery of sub-activities 2.2 and 2.3. Errors validating results.	Medium	Map stakeholders, their history and current roles in the restoration chain. Map organizations that support farmers and invite them to the event. Map stakeholders with extensive expertise to contribute to the validation. Ensure the presence of the technical coordinator in the validation workshops.

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continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
3.1 Map the forestry chains in each Brazilian biome and identify the main bottlenecks and ecological and economic opportunities	Technical risk	Difficulty understanding the nuances and characteristics of each chain in each biome and state. Lack of validation of the activity results.	Low	Analyze previous studies and look for what could be refined for this activity. Conduct a workshop at the start the activities to define the study methodology, and validate the results with the same stakeholders at the end of the activity.
3.2 Implement and monitor 12 mixed plantation demonstration pilot units for restoration	Technical risk, institutional risk and cost risk	Difficulty implementing and maintaining the units. Difficulty keeping the property owner engaged in the activity.	High	Ensure good planning and coordination so the units are self-sustainable and permanent. In the short term, a resource concession contract should be drawn up for the implementation of the units with a provision for monitoring over two years. Establish TCAs with Ater companies to maintain the units.
3.3 Analysis and implementation of nurseries to supply the forestry restoration chain		Difficulty implementing and maintaining the nurseries. In addition, there is the challenge of implementing new nurseries and maintaining existing ones in the dynamics of the restoration chain. Difficulty keeping stakeholders engaged in the maintenance of the nurseries.	High	Ensure good planning and coordination so the units are self-sustainable and permanent. In the short term, a resource concession contract should be drawn up for the implementation of the units with a provision for monitoring over two years. Establish TCAs with Ater companies to maintain the nurseries.

continues

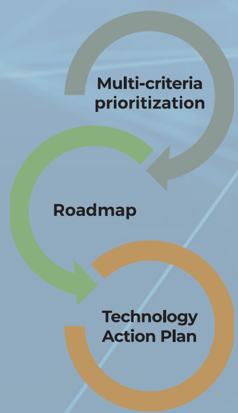
continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
3.4 Development of a platform for the dissemination of benefits and tools to foster mixed plantation silviculture in the restoration chain	Technical risk, organizational risk and institutional risk	Platform potentially not engaging the different interests and characteristics of each organization. Learning difficulties. Risks related to the quality of the courses and content for dissemination. Lack of platform sustainability after the completion of the project.	Medium	Elaborate a questionnaire and apply it to a sample of associations, cooperatives and collectives to guide the construction of the platform. Study similar platforms and their main advantages and disadvantages. Mobilize Ater companies to disseminate and assist people in learning the tool. Establish TCA with an Ater company for the transfer and maintenance of the platform after the completion of the project.
3.5 Elaboration and dissemination of guidelines and education for the development of elective courses on mixed plantation silviculture technologies for higher education degrees in Earth and Exact Sciences and Engineering	Institutional risk and organizational risk	Lack of engagement by teachers not used to digital teaching resources. Difficulty understanding the educational objectives. Difficulty contracting specialized labor.	Low	Train teachers who will make the proposal in the area and on results of the project. Contract specialized labor to formulate higher education proposals. Carry out engagement activities at universities, based on the communication plan for the training and dissemination actions.

Source: the author.

12.

Technology Action Plan **for Satellite Monitoring**



12. TECHNOLOGY ACTION PLAN FOR SATELLITE MONITORING

12.1. Definition of technology

Satellite monitoring systems operate using remote sensing technology, a set of techniques that make it possible to obtain data on targets on the Earth's surface (objects, areas, phenomena) by recording the interaction of electromagnetic radiation with the surface via long distance, or remote, sensors. This technology makes it possible to monitor both land use and land cover changes, as well as rural activities on the landscape.

High-resolution spatial data is capable of supporting decision making at the rural property level. Currently, remote sensing applications assist agricultural production in the early detection of pests and damage to crops, in addition to assessing nutrient levels in plants, detecting water stress and forecasting harvests at the field level (MAES; STEPPE, 2019). As in the case of environmental restoration, the current use of remote sensing in precision agriculture (PA) is mainly via unmanned aerial vehicles (UAVs). However, in the coming years, and with the greater availability of high-resolution images, it will be possible to carry out this analysis using satellite data. Diffusing this technology and providing access to small and medium rural producers can provide socioeconomic benefits in the agricultural development of the country.

Another important application of satellite monitoring is tracking agricultural production. By monitoring changes in land use at the rural property level, and in conjunction with spatially explicit modeling techniques, it is possible to monitor compliance with Forest Code regulations and detect illegal deforestation and its role in the production chain. In addition to ensuring greater transparency at the level of chain sustainability, satellite monitoring is also important for identifying producers who employ more sustainable production methods.

In view of the importance of monitoring for enforcing compliance with the Brazilian Forest Code and the increase in agricultural productivity, the improvement of these systems can contribute to improving forest restoration aimed at environmental regularization and a reduction in illegal deforestation. Thus, these systems indirectly contribute to carbon stocks and a reduction in GHG emissions from land use change.

Currently, there are 713 satellites in Earth orbit with instruments for Earth observations. Most sensors produce images of moderate resolution, with each pixel representing between 30 and 20 meters of the Earth's surface. In recent years, an increasing number of satellites with high resolution sensors have been launched, and currently there are 65 instruments in orbit that can provide images with 5 meters of resolution, or even a few centimeters (ITC, 2019).

In December of 2019, one of the most modern Earth observation satellites was launched: the Sino-Brazilian CBERS-4 satellite, which has three sensors - a wide-field imaging (WFI) camera, a multispectral imaging (MUX) camera and a multispectral and panchromatic wide-scan (WPM) camera (BRASIL; CHINA, 2019). Every five days, WFI imaging provides low resolution images (55 meters), which will be used to assist in Deter-B surveillance activities. MUX imaging captures medium resolution images (16 meters), which will be important for the annual monitoring of deforestation in the Prodes project and agricultural land use for the TerraClass system. The WPM camera provides panchromatic images (white and black) with 2 meters of resolution and multispectral 8-meter imaging, which supports new applications for high resolution monitoring.

Given the growing availability of satellite images (many of them free), the main challenge for the development of new generation high-resolution monitoring systems is no longer the availability of images, but the processing and classification of these images for generating spatial data (ZHANG et al., 2020). Specifically, in the context of satellite monitoring of land use and land cover change, it is important to highlight the need for developing systems that use land cover and land use data to generate data on climate risks and identify the best agricultural practices at the property level, in addition to supporting the implementation of environmental legislation and territorial planning. In this way, end users, whether agricultural producers, banks and buyers or the government, can access updated and detailed data to support their decision-making processes.

12.2. Scope and goals

In this context, this TAP aims to expand the adoption of satellite monitoring of landscapes, with the provision of data based on high resolution images for rural producers and public authorities across Brazil. Specifically, the goal is to develop a monitoring system by 2030 that uses high resolution images (<5 meters) and automatic recognition techniques to provide annual data on land cover and land use in at least two biomes (Amazon and Cerrado) in the following categories: native vegetation (at different levels of degradation), secondary vegetation (at different stages of regeneration), pastures (with different levels of productivity and degradation) and agricultural crops (distinguishing the main crops).

In addition, given the importance of monitoring for the surveillance and enforcement of compliance with the Forest Code, and the increase in agricultural productivity, the data provided by the new monitoring system will serve as a basis for the development of a support system for the implementation of the Forest Code Environmental Recovery Plan (PRA) and the intensification of agriculture.

Table 115 – TAP scope and goals

SCOPE	GOALS
Expand the adoption of satellite monitoring of landscapes, with the provision of data based on high resolution images for rural producers and public authorities across Brazil.	Develop a monitoring system by 2030 that uses high resolution images (<5 meters) and automatic recognition techniques to provide annual data on land cover and land use in at least two biomes (Amazon and Cerrado) in the following categories: native vegetation (at different levels of degradation), secondary vegetation (at different stages of regeneration), pastures (with different levels of productivity and degradation) and agricultural crops (distinguishing the main crops). This data will also be the basis of a support system for the implementation of the Forest Code Environmental Recovery Plan (PRA) and the intensification of agriculture and livestock farming.

Source: the author.

12.3. Actions and activities

Critical gaps and barriers and means to overcome them

Initially, we identified 11 major barriers to the development of satellite monitoring in Brazil. Among these, we identified four critical barriers to the diffusion of the technology, considering the project's 2030 implementation deadline.

First, there is no national strategy for the development of monitoring systems, resulting in the replication of efforts and poor planning to harmonize current systems and develop the next generation of systems. Another critical barrier is the lack of investment in applied research for the development of automatic identification methods using high resolution images. Given the lack of methods with satisfactory accuracy, most of the systems currently in use in Brazil (for example, Inpe's Prodes project and the IBGE land use monitoring system) use visual interpretation of medium resolution images. The third barrier is the failure to use spatial data for territorial intelligence applications to support the implementation of the Forest Code and the intensification of livestock farming. These barriers result in the inadequate use of geospatial technologies, especially by small and medium producers and public authorities.

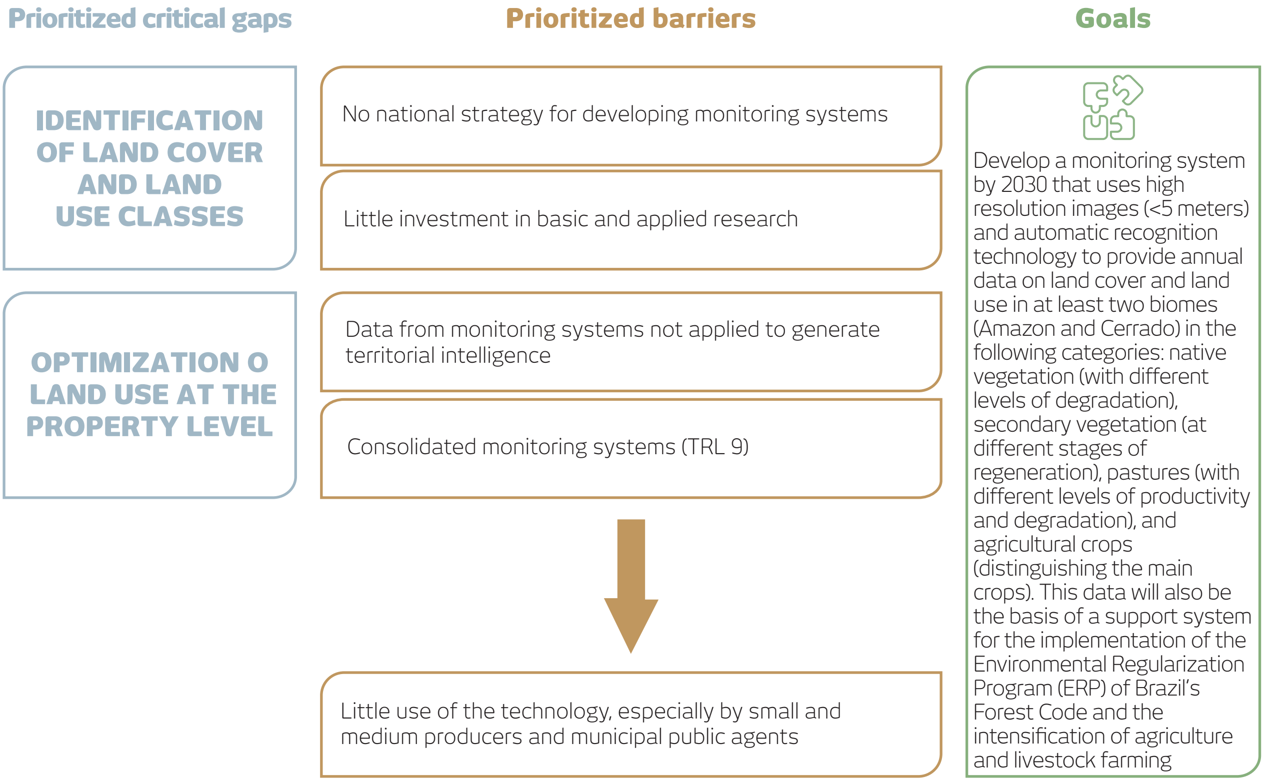


Figure 28 – Critical gaps and barriers and priority goals

Source: the author.

Actions and activities

To achieve the TAP goals, there are five inter-related actions to be carried out in a coordinated sequence. Action 1 serves as the basis for the development of the technology and aims to create a Committee for the establishment, monitoring, review and validation of technical criteria, guidelines and results of the actions for the harmonization of current and future satellite systems for monitoring land use and land cover. Concomitantly, Action 2 aims to develop and validate an automatic classification methodology for land use and land cover monitoring using high resolution satellite images. Actions 3 and 4 aim to develop and provide a high resolution monitoring system and a territorial intelligence system to support the implementation of the Forest Code and the intensification of agriculture and livestock farming, respectively. Finally, Action 5 aims to promote the dissemination and training for using the systems developed in Actions 3 and 4 for public and private stakeholders.

Each action is composed of sub-activities for the step-by-step implementation of the TAP.

Action 1 and related activities

It is important that the monitoring and support system be developed with the best quality practices. To this end, we propose the creation of a Committee for the establishment, monitoring, review and validation of technical criteria, guidelines and results of the actions for the harmonization of satellite systems for monitoring land use and land cover (Action 1). The main goal of this Committee is the harmonization of current monitoring systems and the specification of criteria for future developments. In addition, the Committee will have the additional task of validating and reviewing the results of the other TAP actions.

Action 1 involves five sub-activities. The first is aimed at the institutional structure of the Committee and defines the mission, objectives, guidelines, operating strategy and role of the stakeholders involved in the organization. In addition, this sub-activity defines the short-, medium- and long-term objectives. The second sub-activity aims to define strategies, performance models and stakeholders. It identifies the main producers (for example, Inpe, IBGE, Directorate of the Geographic Service of the Brazilian Army - DSG / EB) and consumers (for example, Mapa, MMA, Embrapa, SFB, State Environmental Agencies, environmental NGOs, private sector representatives) of satellite remote sensing data on land use and land cover. This is followed by a detailed analysis of the different federal government agency satellite monitoring systems and projects, identifying synergies, overlaps and ways to improve these initiatives. The results of this analysis will be disseminated using a communication plan.

The third sub-activity aims to establish technical criteria and guidelines for harmonizing monitoring systems. To this end, it defines a process for evaluating current monitoring systems, issuing technical opinions on whether to maintain, expand, cancel (in the case of duplication) or improve the current systems. It also involves a survey of the data needs of the different geospatial data users, with special attention to the classification labels for land use currently used in these systems and the need for improvements. The monitoring system evaluation processes carried out by the National Satellite Monitoring Committee will also be aligned with the processes for allocating public and international resources for the development of new systems.

The fourth sub-activity is institutional and aims to define the physical structure, available resources and the permanent and support teams to be contracted for the Committee Secretariat. The fifth sub-activity involves the monitoring, review and decision-making process for validating technical criteria, guidelines and the results of the actions for harmonizing satellite systems for monitoring land use and land cover.

Table 116 – Action 1 and related activities

ACTION 1 – CREATION OF A COMMITTEE FOR THE ESTABLISHMENT, MONITORING, REVIEW AND VALIDATION OF TECHNICAL CRITERIA, GUIDELINES AND RESULTS OF THE ACTIONS FOR HARMONIZING SATELLITE SYSTEMS FOR MONITORING LAND USE AND LAND COVER	
Sub-activity 1.1	Define the Committee mission, objectives and organizational guidelines
Sub-activity 1.2	Define strategy, communication plan, business models and stakeholders
Sub-activity 1.3	Establish technical criteria and guidelines for the harmonization of monitoring systems
Sub-activity 1.4	Define physical structure, available resources and permanent and support teams for the Committee
Sub-activity 1.5	Monitoring, review and decision-making process for the validation of technical criteria, guidelines and results of the actions for the harmonization of satellite systems for monitoring land use and land cover

Source: the author.

Action 2 and related activities

In addition to creating the Committee, a fundamental step in the development of the monitoring system is to develop and validate the supervised automatic classification process for monitoring land use and land cover using high resolution satellite images, ensuring they are elaborated in accordance with best quality practices (Action 2). To this end, it is necessary to carry out the five sub-activities. The first is to verify the availability of high resolution satellite images (<5 meters) and their technical characteristics. This involves defining the type of high resolution satellite image with the most potential and satisfactory cost-benefit ratio for the development of the monitoring system based on a multi-criteria evaluation methodology. Establishing key targets (primary and secondary vegetation, pastures and main crops), territorial coverage (sampling versus national territory) and temporal (intra-annual versus multiple years) is necessary for carrying out the research. Finally, this activity includes the acquisition and systematization (collection and processing), with the established criteria, of free images (or via partnerships) in a set of high-resolution images. In view of the high cost to acquire images, additional efforts will be made to use free images. This activity also includes a risk analysis of dependence on satellite images from other countries or commercially available ones, and the need to invest in the production of images with national satellites. Thus, in addition to the acquisition of images from existing satellites, this activity can contribute to the agenda for developing and launching Brazilian satellites. At this stage, the need to modify labels and simplify the classification process will also be evaluated, in order to guarantee the desired accuracy.

With these images, the next step is the mapping of land use and land cover by means of visual interpretation of key landscape targets (primary native vegetation at different levels of degradation, secondary vegetation at different stages of regeneration, pastures at different levels of productivity and degradation, and agricultural crops, with the distinction between the main crops - sub-activity 2.2). This requires defining protocols for interpreting satellite images and a standard for generating attributes, aligned with the objectives established in the previous activity. The definitions of primary and secondary vegetation in the early, mid and advanced stages of regeneration will also be considered, as defined by the National Environment Council (Resolution nº 388/2007). Then, pilot mapping will be carried out on the key targets, considering at least one of the mapping categories in each of the biomes (for example, 10 categories x 6 biomes = 60 types of target). Field checks (ground truthing) of the areas mapped in the pilot activity will also be carried out to validate and improve the visual interpretation protocols. Finally, mapping will be performed to establish the labels used in the next activity.

Finally, sub-activity 2.3 involves the development and validation of the supervised automatic classification methodology for high resolution satellite images. This includes a systematic review of the literature on the methods currently applied for the classification of land cover and land use using remote sensing and emerging methods. It also defines the methods to be tested from the review in the previous activity. Then, the computational performance and accuracy of the selected methods will be evaluated in relation to the mapping based on visual interpretation of the key targets. Finally, a pilot mapping of a subset of land use classes for the Amazon and Cerrado biomes will be carried out at two points in time. This step also verifies the degree of automation the methodology will provide, considering the level of human interpretation after processing, in order to correct errors and validate results.

Table 117 – Action 2 and related activities

ACTION 2 – DEVELOPMENT AND VALIDATION OF SUPERVISED AUTOMATIC CLASSIFICATION OF LAND USE AND LAND COVER MONITORING USING HIGH RESOLUTION SATELLITE IMAGES	
Sub-activity 2.1	Evaluation of the availability and technical characteristics of available satellite images with less than 5 meters of resolution
Sub-activity 2.2	Mapping with visual interpretation of key targets
Sub-activity 2.3	Development and validation of supervised automatic classification methodology for high resolution satellite images

Source: the author.

Action 3 and related activities

With the methodology for automatic classification of high-resolution satellite images, the next step is to apply this scientific knowledge to develop a monitoring system. To this end, there are six activities. Sub-activities 3.1, 3.2 and 3.3 share a common objective: defining the technical structure of the monitoring system, including determining the technical team for the development and maintenance of the system (sub-activity 3.1) and defining the technical needs and technical-financial sustainability of the system. Sub-activities 3.4 to 3.6 involve the implementation, validation and launch of the monitoring system, respectively.

While the systems currently used in Brazil are sufficient for monitoring deforestation, this new system is important because it will allow the country to take advantage of the technological potential of high-resolution images for monitoring forest restoration and precision agriculture by 2030.

Table 118 – Action 3 and related activities

ACTION 3 – DEVELOPMENT AND PROVISION OF A HIGH RESOLUTION MONITORING SYSTEM	
Sub-activity 3.1	Define technical team and institutions responsible for the development and maintenance of the system
Sub-activity 3.2	Define detailed technical requirements of the monitoring system
Sub-activity 3.3	Develop a technical-financial sustainability plan for the monitoring system
Sub-activity 3.4	Implement monitoring system with annual data generation and coverage of, at least, the Cerrado and Amazon biomes
Sub-activity 3.5	Validate the pilot system developed in workshops, per biome
Sub-activity 3.6	Launch the system, with data available on the internet

Source: the author.

Action 4 and related activities

Based on the land use and land cover data from high resolution images in the previous activity, an intelligence system will be developed to support the implementation of the Forest Code and the intensification of agriculture and livestock farming. While Action 3 provides a monitoring system, in order to make the data it generates relevant for actions by public and private stakeholders, it is necessary to aggregate additional data. In the case of the Forest Code, it is necessary to integrate data on deforestation and, especially, vegetation regeneration in the National Rural Environmental Registry System (Sicar), in order to monitor compliance with the Environmental Regularization Program (PRA) stages. This implies, for example, implementing spatially explicit models that assess the requirements of the Forest Code for the recovery of protected areas (APPs) along rivers, taking into account the width of the river and the size of the property (RAJÃO et al., 2020). With respect to the intensification of agriculture, the development of a territorial intelligence system will provide relevant data for the implementation of precision agriculture practices for small and medium producers. This includes data on the state of crop development, soil moisture and other parameters obtained with remote sensing.

The actions share the same set of activities for their development: sub-activities 4.1, 4.2 and 4.3 have a common objective, which is to define the technical structure of the monitoring system, including determining the technical team for developing and maintaining the system and detailing the technical requirements and the technical-financial sustainability plan. Sub-activities 4.4 to 4.6 involve the implementation, validation and launch of the system.

Table 119 – Action 4 and related activities

ACTION 4 – DEVELOPMENT AND PROVISION OF A TERRITORIAL INTELLIGENCE SYSTEM TO SUPPORT THE IMPLEMENTATION OF THE FOREST CODE AND THE INTENSIFICATION OF AGRICULTURE AND LIVESTOCK FARMING	
Sub-activity 4.1	Define technical team and institutions responsible for the development and maintenance of the system
Sub-activity 4.2	Determine detailed technical requirements to support the implementation of the Forest Code
Sub-activity 4.3	Develop a technical-financial sustainability plan for the territorial intelligence system
Sub-activity 4.4	Implement a support system for the implementation of the Forest Code and intensification of agriculture and livestock farming for, at least, the Cerrado and Amazon biomes
Sub-activity 4.5	Validate the pilot system developed in the activity in workshops with key users
Sub-activity 4.6	Launch the system, with data available on the internet

Source: the author.

Action 5 and related activities

The success of the systems developed in the previous actions depends on training and dissemination campaigns for both public and private sector stakeholders. To this end, Action 5 involves four sub-activities to disseminate the systems and train potential users, aligned with the communication plan (sub-activity 1.2)

Sub-activity 5.1 involves developing classroom and distance education training programs on the use of monitoring and support systems for the implementation of the Forest Code and the intensification of agriculture and livestock farming. This training program will be offered to stakeholders who can multiply the dissemination on the use of the systems in four one-semester classes for 30 students. At the same time, dissemination and training events on the use of the systems (using DE tools and webinars) will be held in each Brazilian biome, as well as engagement activities with the states, in order to encourage key government agencies in ten states to adopt the systems.

Finally, we should highlight the importance of incorporating this knowledge in undergraduate courses in the Exact and Earth Sciences and Engineering, encouraging universities to revise curricula through the development and dissemination of guidelines for elaborating elective courses on remote sensing and geoprocessing in higher education degrees in environmental and agricultural programs.

Table 120 – Action 5 and related activities

ACTION 5 – DISSEMINATION AND TRAINING ON THE USE OF MONITORING AND TERRITORIAL INTELLIGENCE SYSTEMS FOR PUBLIC AND PRIVATE STAKEHOLDERS	
Sub-activity 5.1	Develop classroom and distance education training programs on the use of monitoring and support systems for the implementation of the Forest Code and the intensification of agriculture and livestock farming
Sub-activity 5.2	Conduct training programs with stakeholders to multiply dissemination of the use of the systems in four one-semester classes for 30 students
Sub-activity 5.3	Carry out dissemination and training events on the use of the systems (using distance learning tools and webinars) in each Brazilian biome
Sub-activity 5.4	Encourage key government agencies in ten states to adopt the systems
Sub-activity 5.5	Develop and disseminate guidelines for the elaboration of elective courses on monitoring systems in higher education degrees in Exact and Earth Sciences and Engineering

Source: the author.

12.4. Identification of stakeholders and time frame

Stakeholders to be mobilized to implement the TAP

For each of the five actions, we prospected different stakeholders in the public and private sectors and NGOs, among others, who could collaborate in the implementation of satellite monitoring technology.

We identified stakeholders with recognized expertise in the technology with missions aligned with the TAP goals. Among the potential stakeholders, the following can be highlighted: i) general coordination (MCTI); ii) technical coordination (Inpe); iii) coordination of technology promotion and securing financing (ME, Finep, Caixa and BNDES); iv) formalizing data use needs from the monitoring system and technical partners (Mapa, MMA, IBGE, DSG/EB and Embrapa, among others); v) technical support (Brazilian Research Network on Global Climate Change - *Rede Clima*, Management and Operational Center for the Amazon Protection System - Censipam and researchers from universities, among others); and vi) dissemination and training (NGOs, CNA, National Association of Municipal Environmental Bodies- Anamma, and the Brazilian Association of State Environmental Entities - Abema, among others).

We should highlight the expertise of Inpe, given its more than 50 years of experience in the entire value chain related to satellite monitoring systems, the development of hardware and the use of data in applications in environmental and agricultural areas. Thus, we recommend that Inpe be responsible for technical coordination, and the MCTI assume the general coordination of the TAP.

Table 121 – Main stakeholders to involve in implementing the TAP

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
MCTI	The MCTI is involved in the following areas: national telecommunications policy, scientific and technological research, information technology and automation, among others. Given its extensive expertise in satellite monitoring solutions, it could assume the general coordination of the TAP.
ME	Responsible for the formulation and execution of the national economic policy and the financial administration of the State. It could support the financing process and partnerships with financial institutions to finance the TAP.
MMA	The MMA is responsible for: a) national policies for the environment and water resources; b) policies for the preservation, conservation and sustainable use of ecosystems and biodiversity and forests; c) proposing strategies, mechanisms and economic and social instruments to improve environmental quality and the sustainable use of natural resources; d) policies for the integration of the environment and production; e) environmental policies and programs for the Amazônia Legal region (designated Amazon zone); and f) ecological-economic zoning. It could act in the technical coordination related to the formalization of the demand for data from the monitoring system for the implementation of environmental policies.
Mapa	Mapa is responsible for the management of public policies to promote agriculture and agribusiness and for the regulation and standardization of services in the sector. Under its management, it seeks to integrate the marketing, technological, scientific, environmental and organizational aspects of the productive sector, as well as the supply, storage and transportation of crops and the management of agribusiness economic and financial policy. It could act in formalizing the demand for data from the monitoring system for the implementation of agricultural policies.
Inpe	The National Institute for Space Research (Inpe) is an internationally recognized federal institute in the areas of space and Earth sciences whose mission is to promote science and technology and provide specialized products and services for the benefit of Brazil. It could assume the technical coordination of the TAP.

continues

continuation

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
Embrapa	Embrapa provides R&D and innovation solutions for the sustainability of agriculture for the benefit of Brazilian society. It could be responsible for formalizing the demand for data from the monitoring system for agricultural research, as well as act as a technical partner in the execution of TAP activities
BNDES	BNDES is the main Federal Government instrument for long-term financing and investments in all segments of the Brazilian economy. It could act as a financing agent for TAP activities.
Finep	The Financier of Studies and Projects (Finep) promotes science, technology and innovation in companies, universities, technological institutes and other public and private institutions. It participates throughout the innovation chain, focusing on strategic, structural and impact actions for the sustainable development of Brazil. It could act as a financing agent for TAP activities.
CNPq	CNPq promotes and fosters scientific and technological development in Brazil and contributes to the formulation of national science and technology policies. It could act to support the promotion of TAP activities.
Embrapii	Embrapii provides support for technological research institutions to carry out technology research development projects for innovation in cooperation with companies in the industrial sector. It could play a role in activities to promote the TAP.
IBGE	The Brazilian Institute of Geography and Statistics (IBGE) is the main data and information provider in Brazil, serving the needs of different segments of civil society, as well as federal, state and municipal government agencies. It could collaborate in formalizing the demand for data from the monitoring system to generate statistics and socioeconomic data at the federal level.
DSG/EB	The Directorate of the Geographical Service of the Brazilian Army (DSG/EB) is a technical-normative support body of the Department of Science and Technology (DCT) tasked with supervising activities related to images, geographic and meteorological data, the elaboration of cartographic products, as well as the supply and maintenance of the technical material under its management. It could collaborate in formalizing the demand for the system's data and provide expertise on the use of remote sensing for cartographic surveys.
Censipam	The Management and Operational Center for the Amazon Protection System (Censipam) operates principally in the following areas: meteorology, climatology and hydrology; remote sensing; environmental and territorial monitoring; intelligence; information systems, databases and communication networks. It generates integrated products and services of strategic interest for government institutions. It could act as a technical partner in the execution of TAP activities.
Rede Clima	The mission of the Brazilian Research Network on Global Climate Change (*Rede Clima*) is to generate and disseminate knowledge to enable the country to respond to the challenges of global climate change. It could act as a technical partner in the execution of TAP activities.
SFB	The Brazilian Forest Service (SFB) is responsible for the management of public forests (forest registration and concessions, management and monitoring) and for sustainable forestry development (forest inventory, research and development and the Rural Environmental Registry). It could act in formalizing the demand for data from the monitoring system for the implementation of the Forest Code, as well as fostering integration between the systems developed in the TAP and Sicar.
ANA	The National Water Agency (ANA) is responsible for monitoring water resources in Brazil and coordinating data such as the level, flow and sediment of rivers and precipitation for water planning (water use and the prevention of critical events, such as droughts and floods). It could act in formalizing the demand for data from the monitoring system for the implementation of water policies.

continues

continuation

STAKEHOLDERS	MISSION SUMMARY AND STAKEHOLDER ROLES
NGOs	NGOs monitor the implementation of the Forest Code, and develop and provide tools to monitor the implementation of the Code. Through their network, they also conduct research and provide scientific publications with analysis. They could be target groups for the results and training and collaborators in dissemination actions.
AEB	The Brazilian Space Agency (AEB) is responsible for formulating, coordinating and executing Brazilian Space Policy. It could provide technical support for Action 1.
CNA	The mission of the Brazilian Agriculture and Livestock Confederation (CNA) is to represent, organize and support Brazilian rural producers. It also defends their rights and interests, promoting the economic and social development of the agricultural sector. It could be a target group for the results and training and a potential collaborator in dissemination actions.
Software and technological solution providers	They could act as technical partners in the execution of TAP activities.
Organismos financeiros multilaterais	They could provide financial support for the implementation of the TAP.
Anamma	The National Association of Municipal Environmental Bodies is a civil, non-profit and impartial entity that represents municipal powers in the environmental area with the goal of strengthening Municipal Environmental Systems for the implementation of environmental policies to preserve natural resources and improve the quality of life of citizens. It could be a target group for results and training and a potential collaborator in dissemination actions.
Abema	The Brazilian Association of State Environmental Entities is a civil, non-profit and impartial entity that represents municipal powers in the environmental area with the goal of strengthening Municipal Environmental Systems for the implementation of environmental policies to preserve natural resources and improve the quality of life of citizens. It could act in Action 1, representing the interests of State environmental agencies (Oemas) and as a target group for the results and training and a potential collaborator in dissemination actions.

Source: the author.

Schedule of actions and activities

The time frame for implementing the TAP is eight and a half years, a time believed adequate and sufficient for the technical and financial preparation and implementation of the activities for the technological development of the satellite monitoring system.

Some activities can occur sequentially or in parallel. Note that sub-activity 1.5, carried out by the Committee, occurs over the development of the Plan, since it validates/reviews the results of the other activities. The last four semesters of the Plan are dedicated to sub-activities 5.2 to 5.5, as these involve training and disseminating the systems developed in previous semesters.

Table 122 – TAP implementation schedule

SUB-ACTIVITIES	IMPLEMENTATION SCHEDULE																	
	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
	1 SEM	2 SEM	3 SEM	4 SEM	5 SEM	6 SEM	7 SEM	8 SEM	9 SEM	10 SEM	11 SEM	12 SEM	13 SEM	14 SEM	15 SEM	16 SEM	17 SEM	18 SEM
1.1	■	■																
1.2		■																
1.3		■																
1.4		■																
1.5			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2.1		■																
2.2			■	■	■													
2.3.						■	■	■										
3.1							■											
3.2								■										
3.3								■										
3.4									■	■	■	■						
3.5											■							
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4.5												■						
4.6														■				
5.1														■				
5.2															■	■	■	■
5.3															■	■	■	■
5.4															■	■	■	■
5.5															■	■	■	■

Source: the author.

12.5. TAP implementation costs and financing options

The total cost of the TAP was estimated at approximately BRL 193 million. Among the actions and activities, the implementation of Action 3 accounts for approximately 61% of the entire budget.

It is worth noting that the high-resolution satellite images with national coverage represent the highest costs. As a reference for costs, we used the MMA contract to purchase high-resolution RapidEye images with national coverage in 2012, which cost BRL 87 million (BRASIL, 2016a). However, if images with the necessary characteristics are available for free (or at a lower cost), it will be possible to substantially reduce the total cost of the project. It would also be worth considering the investment of these resources in the development of Brazilian satellites, thus also stimulating national industry and the transfer of technology.

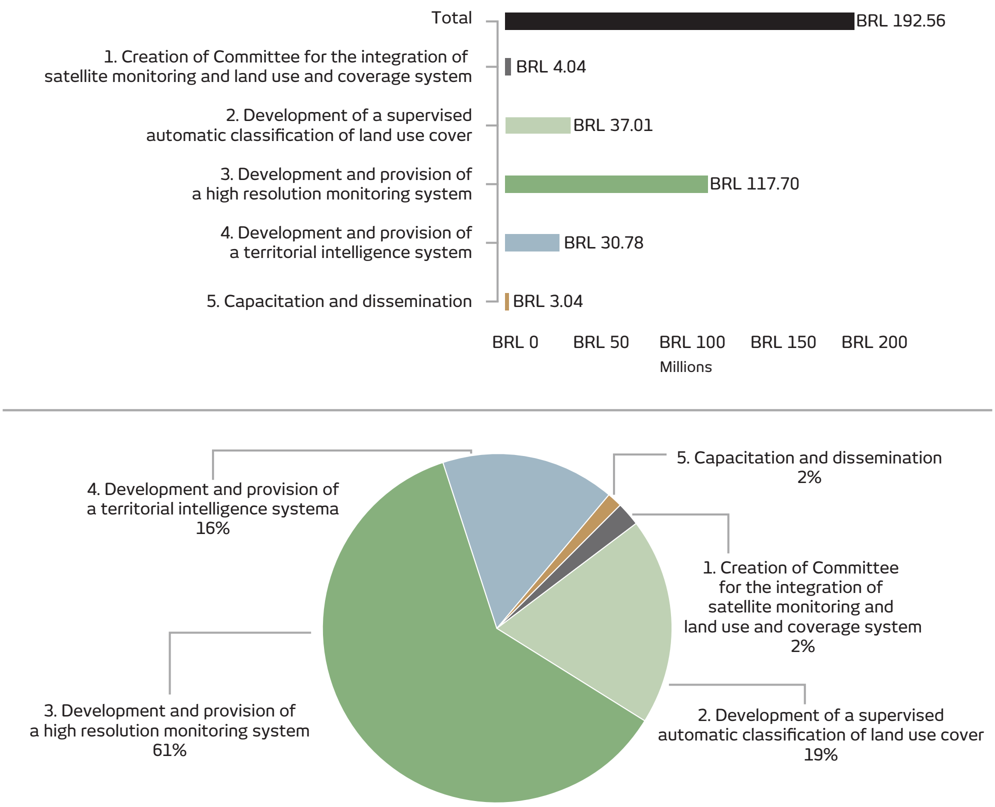

Figure 29 – Total cost per action, in millions of BRL and as a percentage, for the satellite monitoring TAP

Source: the author.

With respect to potential sources of financing for the activities, and with a view to results and a focus on research and development, we determined the typical means of financing would be non-repayable loans and technical assistance. Financing is accessible for state agents (federal, state and municipal), companies (public and micro companies and small, medium and large private sector companies), associations and cooperatives.

More information about financing mechanisms, with a step-by-step guide for filling out project proposals, as well as eligibility criteria, interest rates, terms and support institutions, can be accessed in the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and in the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b).

12.6. Risk and contingency plan

In addition to the cost estimates, we analyzed potential risks to the implementation of the TAP activities. The following risk categories were considered: political, institutional, organizational, technical and cost risks. They were assessed as follows: "low risk" (risks that have minor consequences); "medium risk" (risks that have reversible consequences in the short and medium term with low costs); and "high risk" (risks that have reversible consequences in the short and medium term with high costs). Finally, contingency actions were proposed to mitigate these potential risks.

The risks associated with sub-activities 2.3, 3.4 and 4.1 were considered high. In the case of the first sub-activity, there is a risk of divergence among specialists with respect to automatic classification, the evaluated methods generating results below expectations, delays in previous activities and lack of validation of the methodology. For example, specialists may disagree about the threshold that defines an area as deforested (vis-à-vis an area with degraded vegetation) or a secondary forest at an early stage (vis-à-vis a dirty pasture). To overcome potential divergent classifications, it is important that stakeholders, in conjunction, carefully analyze the classification requirements to align them with expectations. It may be necessary to reevaluate the classification process, discarding or combining classes that have a high degree of uncertainty in the automatic classification system. Contingency resources should be secured for any revisions of the classification system and international experts should assist in the validation process.

Sub-activities 3.1 and 4.3 involve the definition of the technical team and institutions responsible for the development and maintenance of the monitoring and territorial intelligence systems to implement the Forest Code and intensification of agriculture and livestock farming. These activities were classified as high risk, as there may be conflicts between the institutions involved when defining the organization responsible for the development and maintenance of the systems. In addition, contracting specialized labor is complex and there may be a lack of technical coordination and cooperation with the Satellite Monitoring Committee. To mitigate these risks, we suggest establishing objective criteria for the selection of the organization, with clear minimum requirements for institutional capacity, thereby reducing the risk of political interference. Political support from relevant stakeholders is important to avoid significant obstacles. Finally, we suggest contracting labor in centers and institutions with extensive expertise and defining a work plan validated by the Monitoring Committee and the technical coordinator.

Table 123 – TAP activity implementation risks and contingency actions

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.1 Define the Committee mission, objectives and organizational guidelines	Institutional risk and organizational risk	The lack of executive support represents a risk at this early stage, which requires more intense stakeholder participation. There is also the risk that parties may have conflicting interests, as they have different expectations for the project. Difficulty finding quality labor for technical support for the Executive Secretariat of the Committee.	Low	Employ project management methods that aim to harmonize the personal objectives of each representative and balance power during the life cycle of the project. Hold meetings to involve stakeholders with specific responsibilities and expertise for the execution of activities. Contract labor with extensive expertise in monitoring systems. Validate mission, objectives and guidelines with experts.
1.2. Define strategy, communication plan, business models and stakeholders		High-level planning is based on assumptions, which is a potential risk during the execution of the project. In addition, there is the risk of not identifying qualified coordinators and key stakeholders to be on the Committee and provide technical contributions.		Carry out detailed strategic planning to identify flawed assumptions and ensure stakeholder committed to the project. Carry out extensive mapping of stakeholder expertise for participation on the Committee. Establish a permanent technical team with extensive expertise in the area to support the Committee.
1.3. Establish technical criteria and guidelines for the harmonization of monitoring systems	Institutional risk, technical risk and political risk	There is the risk that parties may have conflicting interests, as they have different expectations for the project. The parties also tend to defend their own systems, regardless of the advantages of other systems. Risk of duplicated efforts.	Medium	Employ project management methods that aim to harmonize the personal objectives of each representative and balance power. Strengthen the technical area with the contracting of specialists by the Executive Secretariat of the Committee to guarantee quality decisions. Involve high-level political authorities (secretaries and/or ministers) to ensure legitimacy and political support for decisions.

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
1.4 Define physical structure, available resources and permanent and support teams for the Committee	Organizational risk and technical risk	Inconsistent and conflicting requirements are potential risks when working with different organizations. The parties tend to focus on only one part of the product, without a clear idea of the final product. In addition, the absence of a clear division of labor is another risk in this stage of the project. Additionally, there is the risk of not finding qualified labor to carry out the activity.	Low	Require stakeholders to fully describe their interests to align them with expectations, analyzing their feasibility together. Ensure that the division of labor and process structure has a central position in this stage. Finally, contract labor from leading research centers with proven experience in satellite monitoring or related areas.
1.5 Monitoring, review and decision-making process for the validation of technical criteria, guidelines and the results of the actions for the harmonization of satellite systems for monitoring land use and land cover	Organizational risk and technical risk	Inconsistent and conflicting requirements are potential risks when working with different organizations. The parties tend to focus on only one part of the product, without a clear idea of the final product. In addition, there is the risk that the guidelines established in sub-activity 1.3 may not be implemented due to lack of resources and commitment from the technical team. Finally, delays in validation and lack of monitoring can affect the achievement of the TAP goals.	Medium	Require stakeholders to fully describe their interests to align them with expectations, analyzing their feasibility together. Ensure that the division of labor and process structure has a central position in this stage. Establish responsibilities and compliance with deadlines of the technical support team for the Executive Secretariat in contracts. Validate the different products in workshops with the Committee.

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
2.1 Evaluation of the availability and technical characteristics of available satellite images with less than 5 meters of resolution	Organizational risk, institutional risk and technical risk	Potential lack of information and data and lack of available images. There are also uncertainties about the availability of images, given the risks inherent in the development and launch of satellites. Geopolitical factors must also be considered, with the risk of depending on images from foreign satellites. Finally, it is highly complex to contract experts, given the large size of the technical team. Lack of coordination in the activity.	Medium	Ensure best communication methods, channels and protocols for sharing information. Establish TCAs for data access. Assess the need to develop and launch Brazilian satellites with high resolution sensors. Contract a team with expertise in leading research centers. Ensure Committee supervision and contract a team technical coordinator.
2.2. Mapping with visual interpretation of key targets	Technical risk and organizational risk	Divergences in the interpretation of the images can generate inconsistencies in the mapping. Delays in carrying out activities.	Low	Use tests to assess staff skills and training and assign team members to the most appropriate tasks. Review activity results with the technical coordination. Monitor and establish weekly goals for the team.
2.3. Develop and validate supervised automatic classification methodology for high resolution satellite images	Technical risk	Potential divergence among experts regarding automatic classification. Evaluated methods can generate results below expectations. Delays in sub-activities 2.1 and 2.2. Lack of validation of the methodology.	High	Require stakeholders to fully describe their interests to align them with expectations, analyzing their feasibility together. If necessary, reevaluate the classification process, eliminating or combining classes that present a high level of uncertainty in the automatic classification. Establish contingency resource for revisions of the classification system. Invite international experts to assist with the validation process.

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
3.1 Define technical team and institutions responsible for the development and maintenance of the system	Political risk, organizational risk and institutional risk	Potential conflicts between the institutions involved when defining the organization responsible for the development and maintenance of the system. Contracting specialized labor is complex. Lack of technical coordination and cooperation with the Satellite Monitoring Committee. Lack of institutional support for the development of the tool.	High	Establish objective criteria for the selection of the organization, with clear minimum requirements for institutional capacity. Establish the need to define the institution using technical criteria in the system financing contract. Get political support from relevant stakeholders. Contract labor in centers and institutions with extensive expertise. Define a work plan with validations by the Monitoring Committee and the technical coordinator.
3.2 Define detailed technical requirements of the monitoring system	Institutional risk and organizational risk	Lack of institutional support. In addition, poorly defined objectives and only a vague idea of the technological challenge are risks at this stage.	Medium	Develop detailed goals for the technological challenge before launch. Dedicate staff to answer questions and create prototypes of the final product. Ensure the project budget and goals can be reviewed.
3.3 Develop a technical-financial sustainability plan for the monitoring system	Political risk and technical risk	Lack of technical and financial sustainability of the platform after the completion of the TAP. Lack of institutional interest in adopting the system.	Low	Elaborate a plan for the technical and financial sustainability of the system. Contract a company to map potential sources of financing and propose a technical plan for institutions to adopt the system.

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
3.4 Implement monitoring system with annual data generation and coverage of, at least, the Cerrado and Amazon biomes	Organizational risk, technical risk and cost risk	Poorly defined goals and perception of the technological challenge. High implementation costs.	Medium	Ensure flexibility in management, so the project accommodates different goals and objectives. Ensure the representativeness and authority of the system managers, creating strategies to satisfy market interest. Ensure the contracting of the system in the implementation with the support of the Monitoring Committee.
3.5 Validate the pilot system in workshops, per biome	Institutional risk and technical risk	Lack of support from key stakeholders in the validation process. Technical difficulties in representing user needs and modifying the system specifications satisfactorily.		Employ project management methods that aim to harmonize the personal objectives of each representative and balance power during the life cycle of the project. Use best software engineering practices to record the technical requirements and test the pilot system. Validate the system with experts.
3.6 Launch the system, with data available on the internet	Institutional risk, organizational risk and political risk	Lack of executive support and commitment from superiors is a risk in this stage. Lack of interest in the system. There is also the risk that the parties may have conflicting interests, as they have different expectations for the project. Furthermore, inefficient processes for collecting and systematizing project data, especially for the development of performance indicators and targets, are risks in this stage.		Employ project management methods that aim to harmonize the personal objectives of each representative and balance power during the life cycle of the project. Ensure the best communication methods, channels and protocols for sharing information. Implement the system technical and financial sustainability plan. Transfer the platform in a TCA to a federal research institution. Disseminate the system widely, starting with a launch event.

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SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
4.1 Define technical team and institutions responsible for the development and maintenance of the system	Political risk, organizational risk and institutional risk	There may be conflicts between the institutions involved when defining the organization responsible for the development and maintenance of the system. Contracting specialized labor is complex. Lack of technical coordination and cooperation with the Satellite Monitoring Committee. Lack of institutional support for the development of the tool.	High	Establish objective criteria for the selection of the organization, with clear minimum requirements for institutional capacity. Establish the need to define the institution based on technical criteria in the system financing contract. Ensure political support from relevant actors. Contract labor in centers and institutions with extensive expertise. Define a work plan with validations by the Monitoring Committee and technical coordinator.
4.2 Determine detailed technical requirements to support the implementation of the Forest Code	Institutional risk and organizational risk	Lack of institutional support. Poorly defined objectives and perception of the technological challenge are a risk in this stage.	Medium	Develop detailed goals for the technological challenge before launch. Dedicate staff to answer questions and create prototypes of the final product. Ensure the ability to review project budget and goals.
4.3 Develop a technical-financial sustainability plan for the territorial intelligence system	Political risk and technical risk	Lack of technical and financial sustainability of the platform after the completion of the TAP. Lack of institutional interest in adopting the system.	Low	Elaborate a plan for the technical and financial sustainability of the system. Contract a company to map potential sources of financing and propose a technical plan for institutions to adopt the system.

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continuation

SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
4.4 Implement a support system for the implementation of the Forest Code and intensification of agriculture and livestock farming for, at least, the Cerrado and Amazon biomes	Organizational risk, technical risk and cost risk	Poorly defined goals and perception of the technological challenge. High implementation costs.	Medium	Ensure flexibility in management, so that the project accommodates different goals and objectives. Ensure the representativeness and authority of the system managers, creating strategies to satisfy market interest. Ensure the contracting of the system in the implementation with the support of the Monitoring Committee.
4.5 Validate the pilot system in workshops with key users	Institutional risk and technical risk	Lack of support from key stakeholders in the validation process. Technical difficulties in representing user needs and modifying the system specifications satisfactorily.		Employ project management methods that aim to harmonize the personal objectives of each representative and balance power during the life cycle of the project. Use best software engineering practices to record the technical requirements and test the pilot system. Validate the system with external experts.
4.6 Launch the system, with data available on the internet	Institutional risk, organizational risk and political risk	Lack of executive support and commitment from superiors is a risk in this stage. Lack of interest in the system. There is also a risk that the parties may have conflicting interests, as they have different expectations for the project. Furthermore, inefficient processes for collecting and systematizing project data, especially for the development of performance indicators and targets, are risks in this stage.		Employ project management methods that aim to harmonize the personal objectives of each representative and balance power during the life cycle of the project. Ensure the best communication methods, channels and protocols for sharing information. Implement the system technical and financial sustainability plan. Transfer the platform in a TCA to a federal research institution. Disseminate the system widely, starting with a launch event.

continues

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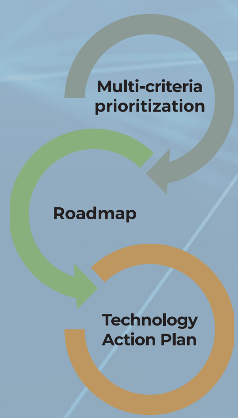
SUB-ACTIVITIES	RISK AND CONTINGENCY PLAN			
	Risk category	Description of risk	Risk assessment	Contingency actions
5.1 Develop classroom and distance education training programs on the use of monitoring and support systems for the implementation of the Forest Code and the intensification of agriculture and livestock farming	Technical risk	Risks related to the quality of training programs. Difficulty contracting specialized labor.	Low	Verification of the material should be carried out by the technical team of the previous activities.
5.2 Conduct training programs with stakeholders to multiply dissemination of the use of the systems in four one-semester classes for 30 students 5.3 Carry out dissemination and training events on the use of the systems (using distance learning tools and webinars) in each Brazilian biome	Technical risk and organizational risk	Risks related to the quality of training programs. Poorly defined program objectives and results are possible risks. Lack of student commitment.	Low	Simplify difficult topics with infographics or other visual aids. Hold regular meetings with open and wide participation to arrive at good solutions. Ensure comprehensive dissemination of the course, preferably by a contracted press professional and ensure coverage in digital media. Ideally, the teachers on the technical team from previous activities should teach training programs.
5.4 Encourage key government agencies in ten states to adopt the systems	Political risk and organizational risk	Lack of support to adopt the technology. Low attendance at events.	Medium	Ensure flexibility in the use of the system so that the project is a platform that accommodates different goals and objectives. Highlight the benefits. Broadly publicize events through digital media.
5.5 Develop and disseminate guidelines for the elaboration of elective courses on monitoring systems in higher education degrees in Exact and Earth Sciences and Engineering	Institutional risk and organizational risk	Lack of engagement from teachers not used to digital teaching resources. Difficulty in understanding the educational objective. Difficulty contracting specialized labor.	Low	Train teachers who will make the proposal in the area and on results of the project. Identify researchers active in educational institutions and encourage them to present proposals for undergraduate and graduate courses. Provide postdoctoral fellowships in remote sensing with the obligation to teach courses in the area.

Source: the author.

13.

Next **Steps**



13. NEXT STEPS

After the completion of the TAPs, we proposed actions to potentialize the implementation of projects for the diffusion and development of the prioritized technologies. It is understood that the cooperation and involvement of the private, public and financing sectors, as well as cooperation agencies, is fundamental to foster sustainable development using technologies that mitigate emissions.

Between October and December of 2020, the National Directorate (ND) of the TNA_BRAZIL project carried out a cycle of webinars entitled "How low carbon technologies can contribute to sustainable development." Seven events were held, and the launch of the event was presided over by Marcos Cesar Pontes, the Minister of Science, Technology and Innovation (MCTI, 2020j; 2020k). During the meetings, the ND and invited experts presented the TAPs, aimed at promoting the diffusion of technologies in the sectors prioritized in the project. The webinars were given ample coverage by the MCTI press office, disseminating the events in news and videos on the MCTI website and YouTube channel (MCTI, 2020c-2020i).

During the process of validating the plans with stakeholders from the Sectoral Chambers (SCs) and the Technical Advisory Committee (TAC), they emphasized the need to improve cooperation and increase national and international support, as well as ensure greater participation from the private sector to ensure access to financial resources for the development and implementation of the prioritized technologies. In addition, in order to ensure the sustainability to the actions, it is essential to carry out actions to disseminate the results of the TAPs, as well as focus on building capacities to implement and monitor the results, particularly of the pilot initiatives, after their implementation. To this end, the TNA_BRAZIL project developed training and dissemination actions for the TAPs, as well as access to national and international financing. Seminars were held in the South, Southeast, Midwest, North and Northeast regions of Brazil to support the adoption of the TAPs, in addition to a webinar on subsidies for financing the technologies prioritized in the TNA_BRAZIL project.

In view of the fact that financing is crucial for the adoption of the TAPs, we prepared the publication "Financing guidelines for technologies and technology action plans of the TNA_BRAZIL project" and the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL project" (BRASIL, 2021a; 2021b). These instruments provide numerous subsidies for access to financing in the form of national and international credit. Moreover, they provide a roadmap for preparing project proposals, according to the different characteristics of the financing mechanisms mapped in the publications.

With a view to advancing the development of projects based on the TAPs, we proposed the following six project ideas. These projects are aligned with the scope and goals of the TAPs. It should be emphasized that the dissemination of these project ideas was prioritized by the ND of the TNA_BRAZIL project in presentations to numerous stakeholders from the private sector, financing agencies and international cooperation agencies, such as the Financier of Studies and Projects (Finep); the Brazilian Development Agency (ABDE); and the United Nations Industrial Development Organization (UNIDO).

These project ideas do not exhaust all the possibilities, and it is understood that interested stakeholders can formulate other proposals based on the goals and scope of the TAPs.

13.1. Precision Agriculture and Industry 4.0

For the agriculture and industry sectors, the TAPs aim to create technology networks aimed at democratizing access to precision agriculture and fostering industry 4.0 technologies. Through pilot projects, the idea is to expand access to precision agriculture by small and medium rural producers and implement industry 4.0 production systems based on automation, digitization and reprocessing of materials.

In synergy with the objectives of the TAPs, we propose the creation of the 4.0 Technology Network in a partnership with public and private sector stakeholders. Once created institutionally, the Network would support the creation of startups to foster the development of technologies in focal sectors (cities, industry, health and agriculture). The next stage involves the establishment of the necessary partnerships for the implementation of eight demonstration pilot projects (2 per sector) of 4.0 technology solutions by 2030, in accordance with the budgetary and segmentation structure of the TAPs for precision agriculture and industry 4.0. Concomitantly with the execution, reporting, verification and dissemination of the results of the pilot initiatives, training on the use and maintenance of the technologies developed should be carried out.

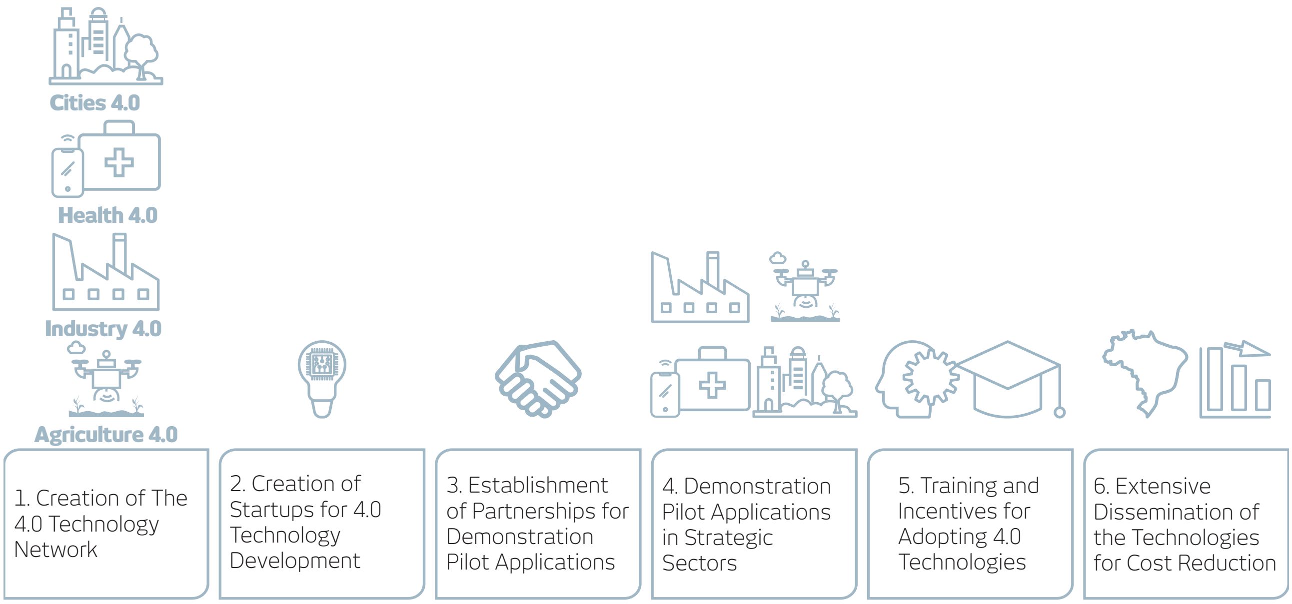


Figure 30 – Brazilian Network for 4.0 Technology Development and Innovation (4.0 Network)

Source: the author.

As shown in the table below, the project offers environmental, economic, social and public health benefits. The cost is estimated at BRL 33.6 million, and can be implemented in nine years.

Table 124 – Project idea for 4.0 technologies in cities, agriculture, industry and health

PROJECT 1	BRAZILIAN NETWORK FOR CIRCULAR ECONOMY AND 4.0 TECHNOLOGY DEVELOPMENT AND INNOVATION (4.0 NETWORK)
Technology	Energy storage; Edge computing; Mist computing; Cloud computing; Machine-to-machine computing; Advanced 5G communications; Digital twins; Geolocation; Georeferencing; Smart sensors; Artificial intelligence; Internet of Things; Additive and predictive maintenance; Advanced materials; Nanotechnology and advanced robotics
Scope	Industry; Cities; Agriculture; Health
Scope of application	National
Main activities	• Creation, management and MRV of the 4.0 Technology Network • Development and implementation of eight demonstration projects • Provision of training courses in 4.0 technologies • Promotion and dissemination of regulations, technical standards and public policies on 4.0 technologies
Benefits	• Gains in the competitiveness of national industry • Improved labor productivity • Reductions in the consumption of energy and natural resources • Reductions in public health spending • Mitigation of GHG emissions and local pollutants • Reductions in industrial and agricultural waste disposal • Demonstration of 4.0 technologies in an operational environment (TRL 7) • Control of epidemics • Creation of new activities and professions in industry
Beneficiaries	Public and private sectors and civil society
Stakeholders to mobilize	• Government bodies • Sector Associations • National and international development agencies • National and international cooperation agencies • Universities and research centers • Professional associations • Companies • Service providers
Implementation period	9 years (2022 - 2030)
Cost (BRL)	33.6 million
Business model	Public-private partnerships, with reimbursable funds to implement the pilot initiatives. Technology transfer at the end of the project. 4.0 technology training, management and promotion activities, with reimbursable resources and technical assistance.

Source: the author.

13.2. Flex Hybrid Vehicles and Ethanol Fuel Cell Electric Vehicles

For the transport sector, we propose to build and test prototype ethanol fuel cells in electric vehicles, as well as retrofit conventional buses to flex hybrid. In both cases, the plans seek to develop national technology and provide options for the increasing trend toward electric vehicles, focusing on the generation of employment and income in the sugar and energy sectors.

One way to scale-up and make the technologies feasible is the constitution of an Innovative Technology Integrated Transport System (ITS). In a public-private partnership, the ITS aims to produce hybridization kits for flex hybrid engines for buses, as well as produce and test a complete pilot serial-connected ethanol fuel cell system in vehicles in different transportation conditions in urban areas across the country. Following this step is the pilot application of the technologies in new vehicles and replacement of internal combustion engines (retrofitting). In this phase, the expectation is to implement the pilot application in a fleet of 300 vehicles (50 cars equipped with ethanol fuel cells and 250 buses retrofitted with flex hybrid engines). Every operation should be monitored and reported to the ITS, which should patent and transfer the technology after the pilot stage for commercial application by partner bus manufacturers and dealers.

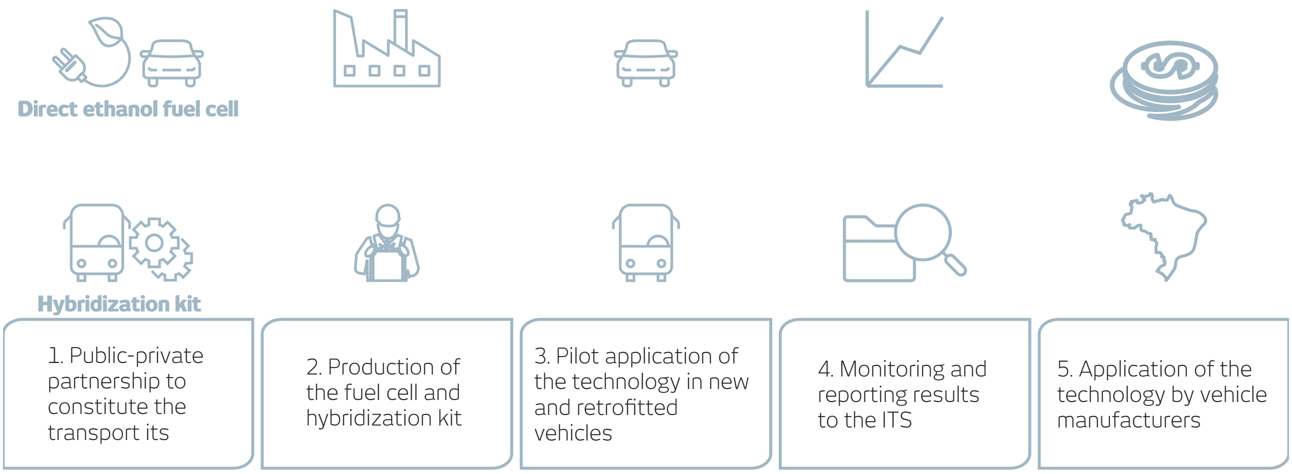


Figure 31 – Innovative Technology Integrated Transport System (ITS)

Source: the author.

The project offers environmental, economic, social and technological benefits, ensuring Brazil's leadership in the technological development of flex fuel cell electric vehicles. The cost of the project is estimated at BRL 134.8 million, with a nine-year implementation period.

Table 125 – Project idea for the creation of an Innovative Technology Integrated Transport System (ITS)

PROJECT 2	INNOVATIVE TECHNOLOGY INTEGRATED TRANSPORT SYSTEM (ITS)
Technology	Hybridization kits for flex hybrid engines; complete pilot serial-connected ethanol fuel cell system
Scope	Transport; Cities
Scope of application	Regional application of the ITS for road transport, with commercialization of technologies by vehicle manufacturers at national and international levels
Main activities	• Constitution of the ITS and the design and installation of the hybridization kit and the pilot serial-connected ethanol fuel cell • Production of hybridization kits and pilot serial-connected ethanol fuel cells • Selection of fleet characteristics and municipalities for the pilot application • Training for the operation and maintenance of pilot applications • Pilot application of hybridization kits in 250 buses (retrofitting) and ethanol fuel cells in 50 cars • Monitoring and reporting of pilot results to the ITS • Patent and transfer of technologies for use by partner bus manufacturers and dealers
Benefits	• Efficiency gains (compared to the internal combustion engine) • Mitigation of GHG emissions and local pollutants • Preservation of jobs and income in the sugar-energy sector • High penetration power in large urban centers, with niche markets • Reductions in public health spending • Development of local technological content, including flex fuel cell electric vehicles • Demonstration of 4.0 technologies in a commercial environment (TRL 7) • Creation of new activities and professions in the automotive industry and bus dealerships
Beneficiaries	Public and private sectors and civil society
Stakeholders to mobilize	• Government bodies • Sector associations • National and international development agencies • National and international cooperation agencies • Universities and research centers • Professional associations • Patent offices and component quality assurance organizations • Auto companies and bus dealerships • Business incubators
Implementation period	9 years (2022 - 2030)
Cost (BRL)	134.8 million
Business model	Public-private partnerships, with reimbursable funding for the assembly and installation of the hybridization kits and pilot serial-connected ethanol fuel cells. Transfer of technologies at the end of the project to automakers and bus dealerships. Other project activities with reimbursable funding and technical assistance.

Source: the author.

13.3. Silviculture and Genetic Improvement of Native Species and Mixed Planting Silviculture for Restoration

The plans propose actions for genetic improvement and mixed planting silviculture in the forestry chain to support restoration and commercial plantations. The actions and activities provide subsidies to foster investments aimed at environmental restoration and recovery while supporting the MCTI's *Regenera Brasil* initiative, whose objective is to contribute to scientific research, technological development and innovation for the generation of guidelines to promote the restoration of native Brazilian ecosystems.

In this context, the project aims to establish a network for the development of technologies to support the restoration and recovery of Brazilian biomes. The first step is creating the network for coordinating actions and activities, with part of the resources dedicated to ensuring the sustainability of the project. The next step is the implementation of 40 nurseries to produce seeds and seedlings of exotic and native species in the Amazon, Cerrado, Caatinga and Atlantic Forest biomes. With the production of seeds and seedlings, pre-commercial scale cultivation of exotic and native species of interest should be implemented and monitored over a period of at least 4 years by the Network. This involves implementing 40 pilot demonstration units for mixed planting of exotic and native species for restoration. Once the technical and economic viability of the crops is established, the seedlings and seeds developed can be patented for commercialization.

All of the aforementioned steps require investments, with long-term economic returns coming solely from the sale of seedlings, the creation of nurseries and wood from crops. In view of the potential for environmental restoration from the commercial implementation of improved species, projects could receive financing through payment for environmental services, which is a financing source that encourages the large-scale diffusion of exotic and native forest species.

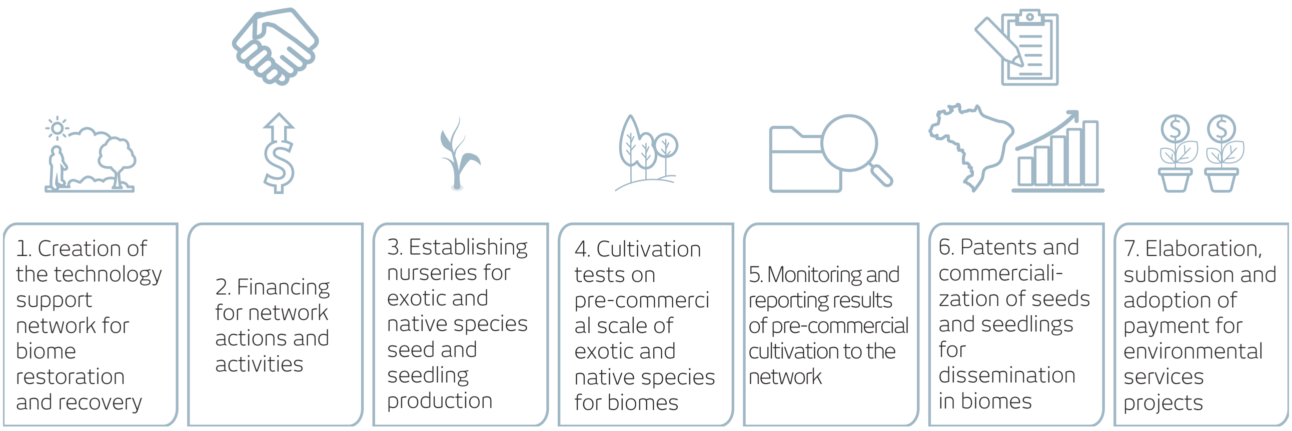


Figure 32 – Technology Network to Support the Restoration and Recovery of Biomes

Source: the author.

As can be seen in the table below, the project offers significant environmental benefits, given the potential for forest restoration and the preservation of biodiversity. The project has an estimated cost of BRL 60 million, and can be implemented in nine years. However, it should be emphasized that revenues from environmental results will only occur in the long term, given the time the mixed planting exotic and native species demonstration units take to reach maturity.

Table 126 – Project idea for the development and implementation of exotic and native tree species silviculture

PROJECT 3	TECHNOLOGY NETWORK TO SUPPORT BIOME RESTORATION AND RECOVERY
Technology	Genetic improvement of tree species (combined provenance-progeny tests); exotic and native seed and seedling nurseries; exotic and native crops for biomes; mixed planting of exotic and native species for restoration
Scope	Forests
Scope of application	Brazilian biomes
Main activities	• Creation, management and MRV of nurseries and pilot demonstration units by the *Regenera* Network • Securing of resources from national and international funding sources • Development of studies on the production of seedlings and seeds in 40 nurseries • Implementation of mineral nutrition programs for seedlings in nurseries and trees in the field • Field (commercial) implementation of exotic and native species • Patents for exotic and native species that are efficient from an ecological, economic and regulatory perspective • Commercialization of exotic and native species • Elaboration and submission of projects for payment for environmental services of the demonstration units • Elaboration of a platform to disseminate the results of the project • Education and training programs for the cultivation of exotic and native species
Benefits	• Forest restoration and recovery • Conservation of biodiversity • Expansion of areas planted with exotic and native species • Mitigation of GHG emissions • Generation of jobs and income in the forestry chain • Commercial demonstration of native species with genetic improvement • Compliance with Environmental Recovery Plan (ERP) regulations
Beneficiaries	Public and private sectors and civil society
Stakeholders to mobilize	• Government bodies • Producer associations and cooperatives • National and international development agencies • National and international cooperation agencies • Universities and research centers • Forestry institutes and state environmental agencies • Forestry sector companies • ATER companies • Rural training service providers
Implementation period	9 years (2022 - 2030)
Cost (BRL)	59.5 million
Business model	Project in partnership with international and national funding agencies with non-reimbursable resources and technical assistance. Given the potential for payment for environmental services, a public-private partnership model could also be adopted.

Source: the author.

13.4. Floating Solar and Innovative Materials for Cement

In the case of the energy and cement sectors, the TAPs promote the diffusion of photovoltaic solar power generation in hydroelectric plant reservoirs and the development of new types of cement with low clinker content. In the case of the energy sector, the starting point is the elaboration of a national inventory of floating solar energy potential. With respect to innovative materials for the production of cement, the goal is to demonstrate the technical, economic and environmental viability of a cement with a clinker content of 50% or less, complemented with other abundant and low-cost raw materials by 2030.

This important project to be developed in parallel with the TAP actions and activities in the TNA_BRAZIL project is aimed at the creation and provision of a platform for the dissemination of sustainable technologies (*Inova Sustentável*), such as floating solar and innovative cement with low clinker content. The starting point is designing the platform and securing financing through national and international financing mechanisms in the form of non-repayable resources and technical assistance for the creation of the platform. Following this, the platform should be validated by technology developers to determine its technical feasibility and possible design modifications. In parallel to the development of the tool, there should be training actions for using and updating the database in the public and private sector. Once the platform is online and running, a monitoring, reporting and verification (MRV) system should be developed for the adoption of technological solutions. To this end, it is important that the tool is interactive and open; that is, it allows users (including suppliers and users of the technologies) to add to the database to update the technical-economic parameters of the technologies, as well as report success stories and lessons learned. Once the platform is available, there should be national and international dissemination actions with respect to the implementation of sustainable technologies using the tool. This involves the creation of digital content and the publication of scientific studies in national and international journals, as well as the actions provided for in the communication plan for the dissemination of the platform. At the end of the project, the platform should be transferred, under a technical cooperation agreement, to an institution with extensive knowledge in the area of sustainable technologies. Ideally, this would be a state technology research center, such as one of the national research and technology institutes.

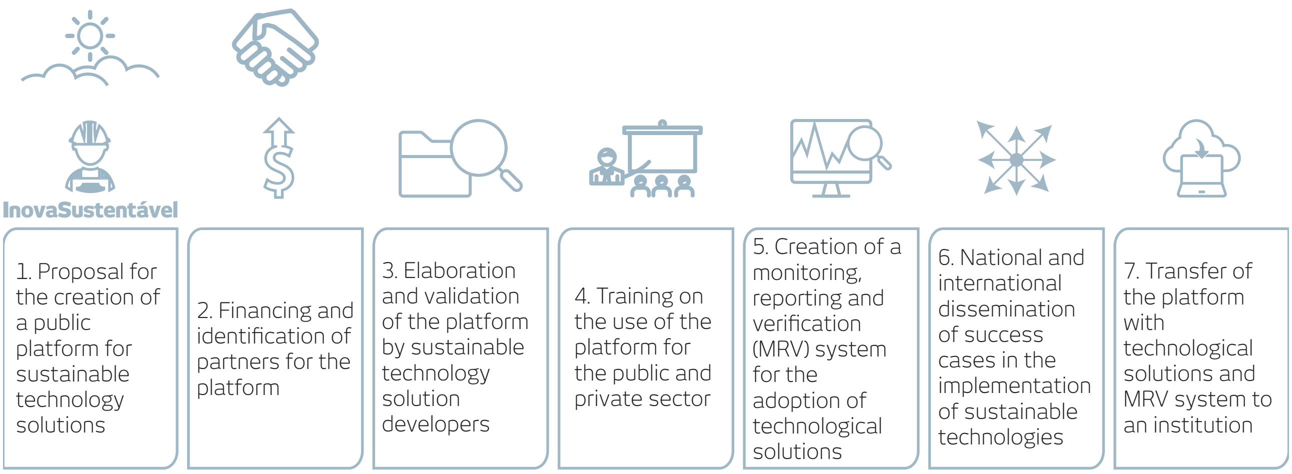


Figure 33 – Platform for the Dissemination of Innovative Sustainable Technologies (*Inova Sustentável*)

Source: the author.

The project offers environmental, economic, social and ecosystem benefits. The implementation cost is relatively low, considering the potential for cross-sectoral adoption of the technologies prioritized in the TNA_BRAZIL project.

Table 127 – Project idea for developing a platform for promoting the application of sustainable technologies based on the TAPs

PROJECT 4	PLATFORM FOR DISSEMINATING INNOVATIONS IN SUSTAINABLE TECHNOLOGY (*INOVA SUSTENTÁVEL*)
Technology	Floating solar power plants; Innovative materials for cement; Energy storage; Solar photovoltaic concentrators; Flex hybrid engines; Ethanol fuel cell electric motors; Biogas plants; Solar photovoltaic induction stoves; Smart meters for electricity distribution; Synchrophasors; Satellite monitoring systems; Territorial intelligence systems; Edge computing; Mist computing; Cloud computing; Machine-to-machine computing; Smart sensors; Artificial intelligence; Internet of Things; Additive and predictive maintenance
Scope	Industry; Cities; Agriculture; Transport; Energy
Scope of application	National
Main activities	• Creation, management and MRV of the *Inova Sustentável* Platform • Financing for the development of the platform • Design, validation and operation of the platform by technology solution developer • Training for using and updating the platform database • Dissemination activities for good practices and lessons learned from the implementation of projects based on the platform • Transfer of the platform to a government agency
Benefits	• Gains in the competitiveness of national industry • Reductions in the consumption of energy and natural resources • Subsidies for developing project proposals for sustainable technologies • Increase in the ratio of renewable energy sources in the national energy matrix • Mitigation of GHG emissions and local pollutants • Reductions in industrial and agricultural waste disposal • Increase in the availability of water for human consumption and generating electricity • Employment and income generation • Conservation of biodiversity • National technological development • Training of human resources for the adoption of sustainable technologies
Beneficiaries	Public and private sectors and civil society
Stakeholders to mobilize	• Government bodies • National research and technology institutes • National and international development agencies • National and international cooperation agencies • Universities and research centers • Companies • Sustainable technology solutions service providers
Implementation period	3 years (2022 - 2024)
Cost (BRL)	2.2 million
Business model	Technical cooperation agreement with the institution responsible for managing the platform, with non-reimbursable funding and technical assistance for the execution of the project.

Source: the author.

13.5. Genetic Improvement in Beef Cattle and Satellite Monitoring

The plans for genetic improvement in beef cattle and satellite monitoring aim to provide subsidies to foster investments aimed at increasing profitability in livestock farming and the dissemination of territorial intelligence systems. It should be noted that the development of platforms with economic, zootechnical, genealogical and genotype data on beef cattle, as well as high resolution and territorial intelligence monitoring systems (proposed in the TAPs) also aim to support public policies in the agriculture, forestry and other land use sectors.

In this sense, the project idea aims to consolidate the genetic improvement in beef cattle and satellite monitoring platforms to provide solutions for decision-making in the agriculture, forestry and other land use sectors. Initially, the structure of the platform has to be designed, partners identified and funding secured from national and international funding sources for its subsequent implementation. It is interesting to note that the platform can be made widely available, but with access restrictions for specific modules, or in full format upon payment of a license fee. This aspect also allows for financing of the project with reimbursable funds.

As the platform depends on the completion of the satellite monitoring and genetic improvement activities in the TAPs, the platform activities should begin in 2025. In this case, training activities on territorial intelligence, monitoring and genetic improvement systems can be shared, with cost savings in scope, as considered in the project budget. Following this, the consolidated platform should be developed, with the plan to transfer it to a selected government research institution. This will ensure the sustainability of the tool, as it will guarantee the maintenance and updating of the modules. In addition, success stories and lessons learned using the agriculture and forestry management tool should be disseminated at the national and international level. It should be emphasized that, in view of the potential benefits from ecosystem services from the application of the tool, consideration should be given to the development of projects for payment of environmental services to ensure financial sustainability for the agency responsible for maintaining and improving the platform.

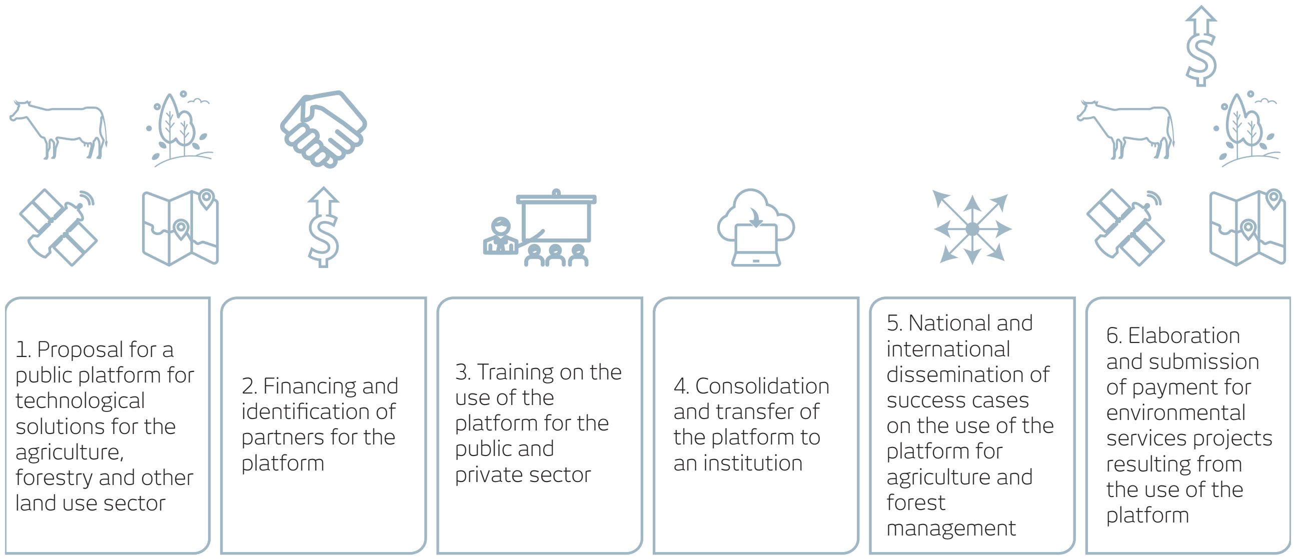


Figure 34 – Platform for training and competitiveness in genetic improvement, satellite monitoring and territorial intelligence

Source: the author.

The project offers environmental, economic, social and ecosystem benefits. To a large extent, it takes advantage of the development costs of the genetic improvement, satellite monitoring and territorial intelligence modules of the TAPs, only requiring additional resources for the activities to integrate these modules in a platform, in addition to training and the dissemination of project results. For this reason, the project has a modest cost of BRL 6.6 million and can be implemented in four years.

Table 128 – Project idea for capacity building to improve competitiveness in genetic improvement, satellite monitoring and territorial intelligence

PROJECT 5	PLATFORM FOR TRAINING AND COMPETITIVENESS IN GENETIC IMPROVEMENT, SATELLITE MONITORING AND TERRITORIAL INTELLIGENCE
Technology	Platform for economic, zootechnical, genealogical and genotype data on beef production; Supervised automatic classification of land use and land cover monitoring via satellite imaging; High resolution satellite monitoring system; Territorial intelligence system
Scope	Agriculture, forestry and other land use
Scope of application	National
Main activities	• Creation, management and MRV of the genetic improvement, satellite monitoring and territorial intelligence platform • Securing financing and identification of partners to make the platform available • Training on using and updating the platform database • Consolidation of modules and transfer of the platform to a selected partner • Dissemination activities on good practices and lessons learned using the platform • Elaboration and submission of projects for payment for environmental services
Benefits	• Gains in profitability of agriculture and livestock farming • Greater use of national genetic material • Mitigation of GHG emissions • Increased herd resilience to climate change • Widespread availability of the integrated platform • Contribution to the implementation of the ERP and precision agriculture • Diffusion of territorial intelligence system • Increased competitiveness in agribusiness • Increase in the quality of spatial data • Maintenance and restoration of ecosystems • Conservation of biodiversity • National technological development • Training of human resources for the adoption of sustainable technologies
Beneficiaries	Public and private sectors and civil society
Stakeholders to mobilize	• Government bodies • Rural extension bodies and producer cooperatives • Agricultural management consulting companies • Government research institutions • Professional associations • National and international development agencies • National and international cooperation agencies • Universities and research centers • Companies • Subnational environmental and agricultural agencies • Technology solution service providers
Implementation period	4 years (2025 - 2028)
Cost (BRL)	6.6 million
Business model	Technical cooperation agreement with the institution responsible for managing the platform, with non-reimbursable and reimbursable funds and technical assistance for the execution of the project.

Source: the author.

13.6. Agricultural and Agro-Industrial Waste for Energy Generation and Photovoltaic Solar Induction Stoves

The TAPs for energy generation from agricultural and agro-industrial waste and photovoltaic solar induction stoves aim to demonstrate technological solutions that promote access to modern energy sources in the waste and buildings sectors (residential, commercial, industrial, public and service buildings). In the case of the waste sector, the scope of co-digestion pilot initiatives allows for the use of the high energy potential of agricultural waste for the production of biogas, thus supporting the *Renovabio* program. For the buildings sector, the plan aims to develop a prototype and pilot implementation of solar induction stoves in households in regions with a high dependency on traditional biomass for cooking fuel.

Aligned with the scope of the plans, we propose to establish an Integrated Technology System (ITS) for renewable power generation in the semiarid Northeast region of Brazil, considering the energy potential of biomass, solar and wind in the region. To this end, a public-private partnership should initially be established for the creation of business incubators for the development of renewable energy technologies in partnerships with local governments and research centers. These partnerships should focus on developing technological solutions for solar power generation and energy storage, mini-grid wind power and biogas plants using agricultural and agro-industrial waste. Education and training actions should be developed to train users in the solutions developed by the ITS (an activity that can be shared with the TAP actions for power generation from agricultural and agro-industrial waste and solar photovoltaic induction stoves). Following this, the intention is to implement 100 demonstration units of the technologies: 45 solar generation units with energy storage; 45 mini wind power generation units; and 10 agricultural waste power generation units in an ICLFS system. In parallel to the pilot applications, the companies incubated at the ITS should carry out monitoring and technical assistance to ensure the sustainability and replicability of the initiatives. Finally, at the end of the project, the lessons learned and good practices resulting from the demonstration units should be disseminated, which will allow these technological solutions to be replicated in other regions in Brazil.

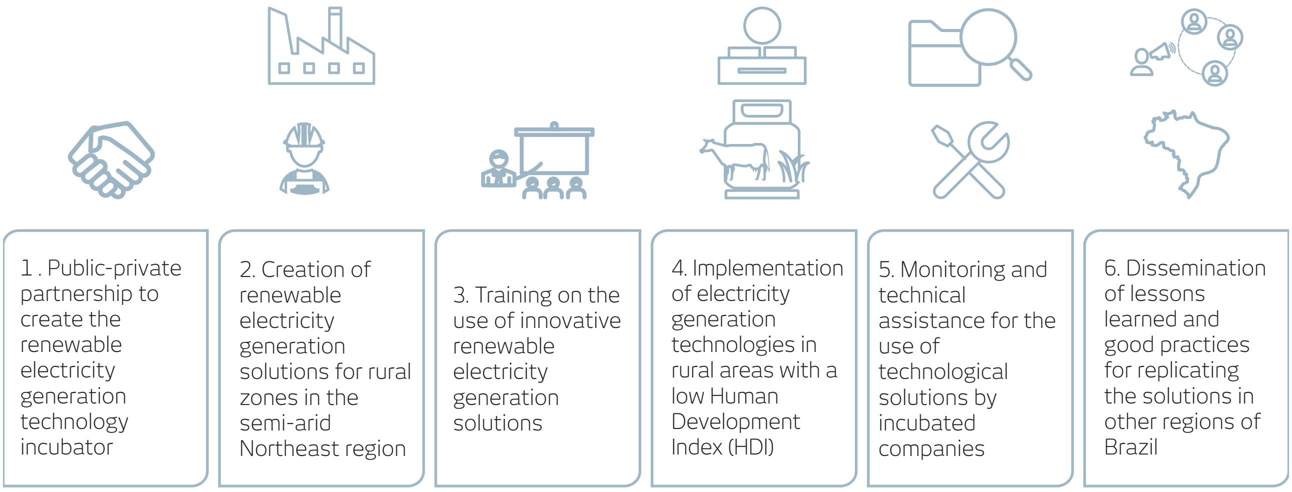


Figure 35 – Integrated Technology System (ITS) for renewable power generation in the semiarid Northeast region

Source: the author.

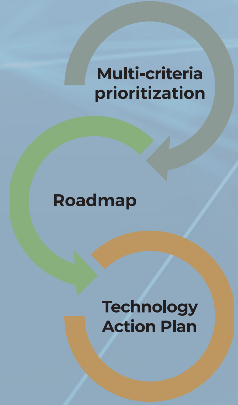
As shown in the table below, the project offers environmental, economic, social and public health benefits. The cost is BRL 19.8 million and can be implemented in nine years.

Table 129 – Project idea for the creation of the Integrated Technology System (ITS) for renewable power generation

PROJECT 6	INTEGRATED TECHNOLOGY SYSTEM (ITS) FOR RENEWABLE POWER GENERATION IN THE SEMIARID NORTHEAST REGION
Technology	Energy storage; photovoltaic solar panels; auxiliary components of photovoltaic systems; solar induction stoves; mini wind generators; biogas plants; anaerobic co-digestion processes
Scope	Cities; Buildings (residential, commercial, public and service buildings); Agriculture
Scope of application	National
Main activities	• Creation of the ITS for renewable power generation technologies • Partnerships with local governments and research centers • Development of technological solutions for solar power generation with energy storage, mini-grid wind power, and energy from agricultural and agro-industrial waste using co-digestion processes • Identification of locations for the implementation of the technologies • Training on the use of the technologies • Pilot application of 100 technology demonstration units • Monitoring and technical assistance to support the demonstration applications of the technologies • Dissemination of lessons learned and good practices for replicating the technological solutions in other regions of Brazil
Benefits	• Increase in the ratio of renewable energy sources in the national electricity matrix • Employment and income generation in the semiarid Northeast region • Contribution to the achievement of the Renovabio targets • Reductions in public health spending • Mitigation of GHG emissions and local pollutants • Reduction in agricultural waste disposal • Demonstration of technologies in an operational environment • Energy autonomy of buildings, with potential revenues from selling surplus power to the grid • Creation of new activities and professions in the semiarid Northeast region • Increased free time for women to pursue remunerated activities
Beneficiaries	Public and private sectors and civil society
Stakeholders to mobilize	• Government bodies • Local governments and research centers • Sector associations • National and international development agencies • National and international cooperation agencies • Universities and research centers • Professional and resident associations • Rural producer cooperatives • Companies • Service providers
Implementation period	9 years (2022 - 2030)
Cost (BRL)	19.8 million
Business model	Public-private partnerships, with reimbursable funds to implement the pilot initiatives. Technology transfer at the end of the project, with payment by users. Training activities and technology promotion with reimbursable funds and technical assistance.

Source: the author.

Conclusions



Conclusions

The Ministry of Science, Technology and Innovations (MCTI), with support from the United Nations Environment Programme (UNEP) and technical partners, prepared these Technology Action Plans (TAPs) within the scope of the *Technology Needs Assessment for the Implementation of Climate Action Plans in Brazil (TNA_BRAZIL)* project to foster the development and diffusion of technologies to promote sustainable development in the country.

Action plans were developed for 12 prioritized technologies based on the application of a multi-criteria methodology in conjunction with key stakeholders from the Technical Advisory Committee (TAC) and Sectoral Chambers (SCs) made up of specialists for the projects: i) precision agriculture; ii) agricultural and agro-industrial waste for energy generation; iii) floating photovoltaic solar energy; iv) photovoltaic solar induction stoves; v) industry 4.0; vi) innovative materials for cement; vii) genetic improvement in beef cattle; viii) satellite monitoring; ix) mixed planting silviculture for restoration; x) silviculture and genetic improvement of native species; xi) ethanol fuel cell electric vehicles; and xii) flex hybrid vehicles.

The importance of the Plans lies in the potential of these technologies to foster economic growth and sustainable development. The actions become even more important in the current context and for the post-pandemic future, as information is essential for the implementation of projects that depend on national or international funding. The action plans were developed with the participation of diverse stakeholders from the private sector, academia and government. Their involvement contributed greatly to making these technologies not only technically and economically viable, but equally importantly, socially acceptable.

The MCTI, and particularly the General Coordination for Climate Science and Sustainability (CGCL), including the National Directorate of the TNA_BRAZIL Project, facilitated the development, consultation and validation of the Action Plans with technical partners from the Technical Advisory Committee (TAC) and specialists from the Sectoral Chambers (SCs) for the agriculture, forestry and other land use; transport; buildings; waste; industry and energy sectors. Based on the analysis and prioritization of the critical barriers to technological development and diffusion, co-benefits were assessed and the plans were prepared to address the following areas: technological scope and goals; actions and activities to achieve the goals; key stakeholders; time frame for implementing the activities; costs; financing options and risk and contingency plans for the implementation of the TAPs.

Consultations for the validation of the TAPs were conducted between March and November of 2020 with members of the TAC and the SCs. They were systematized in matrices, leading to improvements in the plans (MCTI, 2020a; 2020b). The participation of key stakeholders was fundamental for the robustness of the Plans, which were widely disseminated on the official MCTI channels (MCTI, 2020c) and in seven webinars held in November and December of 2020 (MCTI, 2020c-2020i). It should be noted that the Minister of Science, Technology and Innovation inaugurated the cycle of events (MCTI, 2020j; 2020k).

The TAPs focus on removing obstacles that hinder the development and diffusion of prioritized technology packages in Brazil, with implementation schedules that vary from four to eight years, starting in 2021 and concluding by the end of 2030, with the co-benefits achieved. The total cost for adopting the Plans was estimated at BRL 328 million. At the sectoral level, the following TAP objectives can be highlighted:

- For the transport sector, the TAPs propose the development and testing of a prototype ethanol fuel cell in vehicles and flex hybrid technology to retrofit a fleet of diesel buses. In both cases, the TAPs seek to develop national technology and provide options for the increasing trend toward electric vehicles, while ensuring the generation of employment and income in the automotive and sugar and energy sectors.

- For the agriculture and industry sectors, the objective is to create technology networks to democratize access to precision agriculture and foster industry 4.0 technologies. The idea is to expand access to precision agriculture for small and medium rural producers and implement industry 4.0 production systems based on automation, digitization and material reprocessing through the implementation of pilot projects.

- In addition, genetic improvement and mixed planting actions have been proposed for the forestry chain to support restoration and commercial plantations. The TAPs for mixed planting silviculture and genetic improvement of native species provide subsidies to encourage investments in environmental restoration and recovery. At the same time, they support the MCTI's *Regenera Brasil* initiative, whose objective is to contribute to scientific research, technological development and innovation for the generation of guidelines to promote the recovery of Brazilian native ecosystems.

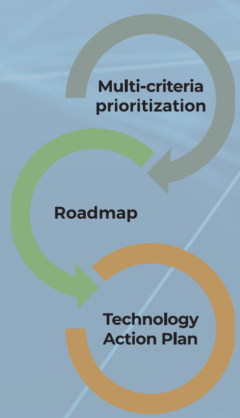
- For the energy and cement sectors, the TAPs seek to diffuse floating solar power generation in hydroelectric plant reservoirs and the development of new types of cement with low clinker content. In the case of the energy sector, the starting point is the elaboration of a national inventory of floating solar energy potential. With respect to innovative materials for the production of cement, the objective is to demonstrate the technical, economic and environmental viability of a cement with a clinker content of 50% or less, complemented with other abundant and low-cost raw materials by 2030.

- The TAPs for genetic improvement in beef cattle and satellite monitoring aim to provide subsidies to foster investments to improve profitability in livestock farming and the dissemination of territorial intelligence systems, which also offer environmental benefits through greater efficiency in agriculture. It should be noted that the development of the platforms proposed in the TAPs for economic, zootechnical, genealogical and genotype data for beef cattle, as well as high resolution and territorial intelligence monitoring systems can also support public policies in the agriculture, forestry and other land use sectors.

- Finally, the TAPs for energy generation from agricultural and agro-industrial waste and photovoltaic solar induction stoves aim to demonstrate technological solutions that promote access to modern energy sources in the waste and buildings sectors (residential, commercial, industrial, public and service buildings). In the case of the waste sector, the scope of co-digestion pilot initiatives allows for the use of the high energy potential of agricultural waste for the production of biogas, thus supporting the *Renovabio* program. For the buildings sector, the plan aims to develop a prototype and pilot implementation of solar induction stoves in households in regions with a high dependency on traditional biomass for cooking fuel.

In parallel to the Plans, it is necessary to improve national and international cooperation and support, with greater participation from the private sector, to guarantee access to financial resources for the development and implementation of the prioritized technologies. Furthermore, to ensure the sustainability of actions, it is important to disseminate the TAP results, as well as to build capacities to implement and monitor the results, especially from the pilot initiatives. To this end, the TNA_BRAZIL project developed activities for training and disseminating results and tools to support of the adoption of the Plans. An example of this is the webinar series "How low carbon technologies can contribute to sustainable development," the regional webinars "Support for the adoption of the Technological Action Plans," the webinar on "Subsidies for financing the prioritized technologies of the TNA_BRAZIL project," and the "Electronic guide to financing options for the technologies prioritized in the TNA_BRAZIL Project." With this, we believe that the project's objectives will be met and surpassed, ensuring Brazil effective results in terms of economic, social and environmental sustainability, thus subsidizing the implementation strategy and contributing to meeting Brazil's NDC targets.

Bibliography



Bibliography

ABCZ. Sistema Integrado de Avaliação Genética. Programa de Melhoramento Genético de Zebuínos. [S.l.], 2020. Available at: https://www.abczstat.com.br/comunicacoes/sumario/GraficosTendencias.aspx. Accessed: Sept. 14, 2020.

BIMAQ – ASSOCIAÇÃO BRASILEIRA DA INDÚSTRIA DE. MÁQUINAS E EQUIPAMENTOS. Missão da Abimaq. [S.l.]: [s.d.]. Available at: http://www.abimaq.org.br/site.aspx/Abimaq-Missao-Politica-Qualidade. Accessed: Nov. 14, 2020.

ABRADI – ASSOCIAÇÃO BRASILEIRA DOS AGENTES DIGITAIS. Guia de Marketing de Conteúdo. São Paulo: Abradi, 2020.

ABY, B. A. et al. Effect of incorporating greenhouse gas emission costs into economic values of traits for intensive and extensive beef cattle breeds. Livestock Science, v.158, p. 1-11, 2013.

ACI TECHNOLOGIES. Department of The Navy. Science & Technology Manufacturing Fuel Cell Manhattan Project. Philadelphia: ACI Technologies, 2011. Available at: https://www.energy.gov/sites/prod/files/2014/03/f12/manufacturing_fuel_cell_manhattan_project.pdf. Accessed: Nov. 12, 2020.

AGÊNCIA DE INOVAÇÃO UFPR. Objetivos. [S.l.]: [s.d.]. Available at: http://www.nitpar.pr.gov.br/agencia-de-inovacao-ufpr/. Accessed: Nov. 14, 2020.

ALVES, R. et al. Disseminação do melhoramento genético de bovinos de corte. Revista Brasileira de Zootecnia, v. 28, n. 6, p. 1219-1225, 1995.

AN, L.; ZHAO, T. S.; LI, Y. S. Carbon-neutral sustainable energy technology: direct ethanol fuel cells. Renewable and Sustainable Energy Reviews, v. 50, p. 1462-1468, 2015.

ANBUMOZHI, V.; KIMURA, F. Industry 4.0: Empowering ASEAN for the Circular Economy. [S.l.]: Eria, 2018. Available at: https://www.eria.org/publications/industry-40-empowering-asean-for-the-circular-economy/#:~:text=This%20book%20investigates%20the%20challenges,paradigm%20on%20circular%20economy%20policy. Accessed: Dec. 14, 2020.

ANFAVEA – ASSOCIAÇÃO NACIONAL DOS FABRICANTES DE VEÍCULOS AUTOMOTORES. Anuário da indústria automobilística brasileira 2019. São Paulo: Anfavea, 2019. Available at: http://www.virapagina.com.br/anfavea2019/. Accessed: Jan. 25, 2020.

______. Sobre a Anfavea. [S.l.]: [s.d.]. Available at: http://anfavea.com.br/a-anfavea. Accessed: Nov. 14, 2020.

ARAMESH, M. et al. A review of recent advances in solar cooking technology. Renewable Energy, v. 140, p. 419-435, 2019.

ASBRAAP – ASSOCIAÇÃO BRASILEIRA DE AGRICULTURA DE PRECISÃO. Sobre a Asbraap. [S.l.]: [s.d.]. Available at: https://asbraap.org/. Accessed: Nov. 14, 2020.

AUSPIN – AGÊNCIA USP DE INOVAÇÃO. A agência. [S.l.]: [s.d.]. Available at: http://www.inovacao.usp.br/agencia/. Accessed: Nov. 14, 2020.

BADWAL, S. P. S. et al. Direct ethanol fuel cells for transport and stationary applications: a comprehensive review. Applied Energy, v. 145, p. 80-103, 2015.

BRASIL. Lei nº 13.576, de 26 de dezembro de 2017. Dispõe sobre a Política Nacional de Biocombustíveis (RenovaBio) e dá outras providências. Diário Oficial da União, Brasília, 2017. Available at: http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2017/lei/L13576.htm. Accessed: Nov. 12, 2020.

______. Decreto nº 10.531, de 26 de outubro de 2020. Institui a Estratégia Federal de Desenvolvimento para o Brasil no período de 2020 a 2031. Available at: https://www.in.gov.br/en/web/dou/-/decreto-n-10.531-de-26-de-outubro-de-2020-285019495. Accessed: Nov. 13, 2020.

BRASIL. Advocacia-Geral da União. Relatório de Avaliação dos Resultados da Gestão. Unidade auditada: Secretaria de Extrativismo e Desenvolvimento Rural Sustentável (SEDR). Exercício 2014. Brasília: AGU, 2016a. Available at: https://auditoria.cgu.gov.br/download/8615.pdf. Accessed: June 19, 2020.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Desenvolvimento Agropecuário e

Cooperativismo. Agenda Estratégica 2014-2030 – Agricultura de Precisão. Brasília: Mapa/ACS, 2014. Available at: https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/tecnologia-agropecuaria/agricultura-de-precisao-1/arquivos-de-agricultura-de-precisao/agenda-estrategica-do-setor-de-agricultura-de-precisao.pdf/@@download/file/agenda-estrategica-do-setor-de-agricultura-de.pdf. Accessed: Sept. 4, 2020.

______. Valor da produção agropecuária de 2019 atinge recorde de R$ 630,9 bilhões. Brasília: Mapa, 2019a. Portal Mapa. Available at: https://www.gov.br/agricultura/pt-br/assuntos/noticias/valor-da-producao-agropecuaria-encerra-2019-com-r-630-9-bilhoes. Accessed: Jan. 14, 2020.

BRASIL. Ministério da Fazenda – MF. Programa País do Brasil para o Fundo Verde do Clima – GCF. Brasília: MF, 2018.

BRASIL. Ministério de Minas e Energia. Renovabio. Brasília: MME, 2018. Available at: http://www.mme.gov.br/web/guest/secretarias/petroleo-gas-natural-e-biocombustiveis/acoes-e-programas/programas/renovabio. Accessed: May 20, 2020.

BRASIL. Ministério da Ciência, Tecnologia e Inovações. Contribuições aos Planos de Ação Tecnológica para o desenvolvimento e difusão das tecnologias priorizadas nos setores da agricultura, florestas e outros usos da terra. Brasília: MCTIC, 2020a. Available at: https://drive.google.com/file/d/1toR3W5JqKh0lK4WPGxvecrMbIqBCExKQ/view?usp=sharing. Accessed: Dec. 26, 2020.

______. Contribuições aos Planos de Ação Tecnológica para o desenvolvimento e difusão das tecnologias priorizadas nos setores do sistema energético. Brasília: MCTIC, 2020b. Available at: https://drive.google.com/file/d/1JYbdx2_K5tN1zx22GXn4AbEEqaTkDFmK/view?usp=sharing. Accessed: Dec. 26, 2020.

______. MCTI Youtube Channel: Playlist Tecnologias de Baixo Carbono. Ciclo de webinários Contribuição das tecnologias de baixo carbono para o desenvolvimento sustentável. Brasília: MCTIC, 2020c. Available at: https://www.youtube.com/watch?v=Q0k-bQRJp_E&list=PLa8HqSGatmeQOU1Yh7bmgkWnWM6f5Nn1g. Accessed: Dec. 26, 2020.

______. Plano tecnológico propõe uso de etanol em veículos elétricos e híbridos para descarbonizar transporte. Brasília: MCTIC, 2020d. Available at: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/noticias/2020/11/plano-tecnologico-propoe-uso-de-etanol-em-veiculos-eletricos-e-hibridos-para-descarbonizar-transporte. Accessed: Dec. 26, 2020.

______. Criação de Redes de tecnologia busca democratizar acesso à agricultura de precisão e fomentar indústria 4.0. Brasília: MCTIC, 2020e. Available at: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/noticias/2020/11/criacao-de-redes-de-tecnologia-busca-democratizar-acesso-a-agricultura-de-precisao-e-fomentar-industria-4.0. Accessed: Dec. 26, 2020.

______. Planos tecnológicos propõem ações de melhoramento genético e plantios mistos na cadeia florestal. Brasília: MCTIC, 2020f. Available at: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/noticias/2020/11/planos-tecnologicos-propoem-acoes-de-melhoramento-genetico-e-plantios-mistos-na-cadeia-florestal#:~:text=Planos%20tecnol%C3%B3gicos%20prop%C3%B5em%20a%C3%A7%C3%B5es%20de%20melhoramento%20gen%C3%A9tico%20e%20plantios%20mistos%20na%20cadeia%20florestal,-Iniciativa%20desenvolvida%20pelo&text=De%20-acordo%20com%20o%20coordenador,mistos%20de%20nativas%20e%20ex%C3%B3ticas. Accessed: Dec. 26, 2020.

______. Produção sustentável de cimento e geração de energia solar fotovoltaica são temas de webinário. Brasília: MCTIC, 2020g. Available at: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/noticias/2020/12/producao-sustentavel-de-cimento-e-geracao-de-energia-solar-fotovoltaica-sao-temas-de-webinario#:~:text=temas%20de%20webin%C3%A1rio-,Produ%C3%A7%C3%A3o%20sustent%C3%A1vel%20de%20cimento%20e%20gera%C3%A7%C3%A3o%20de,fotovoltaica%20s%C3%A3o%20temas%20de%20webin%C3%A1rio&text=%E2%80%9CO%20desenvolvimento%20das%20a%C3%A7%C3%B5es%20tecnol%C3%B3gicas,de%20pain%C3%A9is%20fotovoltaicos%E2%80%9D%2C%20analisa. Accessed: Dec. 26, 2020.

______. Melhoramento genético animal e ampliação de monitoramento por satélite para uso da terra são debatidos pelo MCTI. Brasília: MCTIC, 2020h. Available at: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/noticias/2020/12/melhoramento-genetico-animal-e-ampliacao-de-monitoramento-por-satelite-para-uso-da-terra-sao-debatidos-pelo-mcti#:~:text=debatidos%20pelo%20MCTI-,Melhoramento%20gen%C3%A9tico%20animal%20e%20amplia%C3%A7%C3%A3o%20de%20monitoramento%20por%20sat%C3%A9lite%20para,terra%20s%C3%A3o%20debatidos%20pelo%20MCTI&text=Segundo%20o%20coordenador%20t%C3%A9cnico%20dos,animal%20e%20monitoramento%20por%20sat%C3%A9lite. Accessed: Dec. 26, 2020.

______. MCTI: aproveitamento energético de resíduos agrícolas e agroindústria e fogões solares encerram ciclo de webinários. Brasília: MCTIC, 2020i. Available at: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/noticias/2020/12/mcti-aproveitamento-energetico-de-residuos-agricolas-e-agroindustria-e-fogoes-solares-encerram-ciclo-de-webinarios. Accessed: Dec. 26, 2020.

______. Como superar as necessidades em tecnologias de baixo carbono do Brasil é tema de webinário promovido pelo MCTI. Brasília: MCTIC, 2020j. Available at: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/noticias/2020/10/201ccomo-superar-as-necessidades-em-tecnologias-de-baixo-carbono-do-brasil201d-e-tema-de-webinario-promovido-pelo-mcti. Accessed: Dec. 26, 2020.

______. Como superar as necessidades em tecnologias de baixo carbono do Brasil é tema de webinário promovido pelo MCTI: MCTI Youtube Channel. Brasília: MCTIC, 2020k. Available at: https://www.youtube.com/watch?v=XWwpwhYwqFI&feature=youtu.be. Accessed: Dec. 26, 2020.

______. Estratégia Nacional de Ciência, Tecnologia e Inovação: 2016-2022. Brasília: MCTIC, 2016.

______. Terceira Comunicação Nacional do Brasil à Convenção-Table das Nações Unidas sobre Mudança do Clima – Sumário Executivo. Brasília: MCTIC, 2016b. Available at: https://sirene.mctic.gov.br/portal/export/sites/sirene/backend/galeria/arquivos/2018/10/11/MCTI_TCN_SUMARIO_EXECUTIVO_port.pdf. Accessed: Jan. 26, 2020.

______. Diretrizes de financiamento para as tecnologias e plano de ação tecnológica do projeto TNA_BRAZIL. Brasília: MCTIC, 2021a. Available at: http://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/tna_brazil/tna_brazil.html. Accessed: Jan. 26, 2021.

______. Guia eletrônico das opções de financiamento para as tecnologias priorizadas no projeto TNA_BRAZIL. Brasília: MCTIC, 2021b. Available at: http://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/tna_brazil/tna_brazil.html. Accessed: Jan. 26, 2021.

______. Portaria MCTI nº 3.206, de 25 de agosto de 2020. Institui, no âmbito da Ministério da Ciência, Tecnologia e Inovações, a Iniciativa Regenera Brasil e o respectivo Comitê Gestor. Brasília: MCTI, 25 ago. 2020. Available at: http://antigo.mctic.gov.br/mctic/opencms/legislacao/portarias/Portaria_MCTI_n_3206_de_25082020.html. Accessed: Sept. 17, 2020.

______. Instituto Nacional de Pesquisas Espaciais; CHINA. Academia Chinesa de Tecnologia Espacial. CBERS 04A – 6º satélite sino-brasileiro de recursos terrestres do espaço para a sociedade. São Paulo; Beijing: Inpe; Academia Chinesa de Tecnologia Espacial, Dec. 2019. Available at: http://www.cbers.inpe.br/centrais_conteudo/arquivos/folder_CBERS04A.pdf. Accessed: Nov. 13, 2020.

BRASIL. Ministério da Ciência, Tecnologia, Inovações e Comunicações/Financiadora de Estudos e Projetos (MCTIC/FINEP). SELEÇÃO PÚBLICA MCTI/FINEP/FNDCT. Subvenção Econômica à Inovação – 04/2020: Tecnologias 4.0. Available at: http://www.finep.gov.br/images/chamadas-publicas/2020/16_06_2020_Edital_Subvencao_4_0.pdf. Accessed: Sept. 23, 2020.

BRASIL. Ministério da Ciência, Tecnologia, Inovações e Comunicações/Ministério da Economia (MCTIC/ME). Plano de Ação da Câmara Brasileira da Indústria 4.0 do Brasil. Available at: https://antigo.mctic.gov.br/mctic/export/sites/institucional/tecnologia/tecnologiasSetoriais/Camara_I40__Plano_de_Acao_Camara_brasileira.pdf. Accessed: Sept. 23, 2020.

BRASIL. Presidência da República. Decreto nº 10.052, de 9 de outubro de 2019. Institui a Comissão Brasileira de Agricultura de Precisão e Digital. Diário Oficial da União, Brasília, 2019b. Available at: http://www.planalto.gov.br/ccivil_03/_ato2019-2022/2019/decreto/D10052.htm#:~:text=DECRETO%20N%C2%BA%2010.052%2C%20DE%209,que%20lhe%20confere%20o%20art. Accessed: Sept. 4,. 2020.

CARGILL. Missão. [S.l.]: [s.d.]. Available at: https://www.cargill.com.br/pt_BR/funda%C3%A7%C3%A3o-cargill. Accessed: Nov. 14, 2020.

CARRETTE, L.; FRIEDRICH, K. A.; STIMMING, U. Fuel cells: fundamentals and applications. Fuel Cells, v. 1, n. 1, p. 5-39, 2001.

CHIAVARI, J.; LOPES, C. L. Onde estamos na implementação do Código Florestal? Radiografia do CAR e do PRA nos estados brasileiros. [S.l.]: CPI; Input, 2019. (Report). Available at: https://www.climatepolicyinitiative.org/wp-content/uploads/2019/12/Onde-estamos-na-implementacao-do-Codigo-Florestal.pdf. Accessed: Aug. 2, 2020.

CASAS, Y. et al. Integration of Solid Oxide Fuel Cell in a sugar-ethanol factory: analysis of the efficiency and the environmental profile of the products. Journal of Cleaner Production, v. 19, n. 13, p. 1395-1404, 2011.

CNA – CONFEDERAÇÃO DA AGRICULTURA E PECUÁRIA DO BRASIL. Missão da CNA. [S.l.]: [s.d.]a. Available at: https://www.cnabrasil.org.br/cna/missao-cna. Accessed: Nov. 14, 2020.

______. Missão do Senar. [S.l.]: [s.d.]b. Available at: https://www.cnabrasil.org.br/senar/missao-senar. Accessed: Nov. 14, 2020.

CNI – CONFEDERAÇÃO NACIONAL DA INDÚSTRIA. Caminho estratégico para a indústria brasileira. Brasília: CNI, 2014.

______. Desafios para indústria 4.0 no Brasil. Brasília: CNI, 2016.

COELHO, S. T. et al. The energy transition history of fuelwood replacement for liquefied petroleum gas in Brazilian households from 1920 to 2016. Energy Policy, v. 123, p. 41-52, 2018.

CORADIN, L.; CAMILLO, J.; PAREYN, F. G. C. (Eds.). Espécies nativas da flora brasileira de valor econômico atual ou potencial: plantas para o futuro. Brasília: MMA, 2018. Available at: https://www.mma.gov.br/publicacoes/biodiversidade/category/54-agrobiodiversidade. Accessed: Nov. 14, 2020.

DENTON, T. Electric and hybrid vehicles. London: Routledge, 2016.

DOGDIBEGOVIC, E.; FUKUYAMA, Y.; TUCKER, M. C. Ethanol internal reforming in solid oxide fuel cells: a path toward high performance metal-supported cells for vehicular applications. Journal of Power Sources, v. 449, 2020.

EL-MEMARI NETO, A. C. Como ganhar dinheiro na pecuária: os segredos da gestão descomplicada. 1. ed. Maringá: Inttegra, 2019.

EMATER-PR comemora 60 anos. Asbraer, [s.d.]. Available at: http://www.asbraer.org.br/index.php/rede-de-noticias/item/685-emater-pr-comemora-60-anos. Accessed: Nov. 14, 2020.

EMBRAPA – EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (Brasil). Agricultura de precisão (AP) para sustentabilidade do sistema produtivo agrícola, pecuário e florestal brasileiro. Brasília: Embrapa, 2016. Portal Embrapa. Available at: https://www.embrapa.br/busca-de-projetos/-/projeto/212226/agricultura-de-precisao-ap-para-sustentabilidade-do-sistema-produtivo-agricola-pecuario-e-florestal-brasileiro. Accessed: Dec. 7, 2019.

EPE – EMPRESA DE PESQUISA ENERGÉTICA. Energia Renovável – Hidráulica, Biomassa, Eólica, Solar, Oceânica. Rio de Janeiro: EPE, 2016.

______. Balanço Energético Nacional 2019 – ano-base 2018. Rio de Janeiro: EPE, 2019. Available at: http://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-377/topico-494/BEN 2019 Completo WEB.pdf. Accessed: Nov. 12, 2020.

______. Expansão da Geração – Solar Fotovoltaica Flutuante: aspectos tecnológicos e ambientais relevantes ao planejamento. Rio de Janeiro: EPE, 2020. (Technical Note).

FERNANDES, G.; MARIANI, L. O alto potencial de produção e uso fará do biogás a próxima fronteira da energia renovável no Brasil? Boletim de Conjuntura do Setor Energético, Caderno Opinião, p. 1-12, mar. 2019.

FLORINDO, T. J. et al. Carbon footprint and life cycle costing of beef cattle in the Brazilian Midwest. Journal of Cleaner Production, v. 147, p. 119-129, 2017.

GIDDEY, S. et al. A comprehensive review of direct carbon fuel cell technology. Progress in Energy and Combustion Science, v. 38, n. 3, p. 360-399, 2012.

GIODA, A. Características e procedência da lenha usada na cocção no Brasil. Estudos Avançados, v. 33, n. 95, p. 133-149, 2019.

HAGOS, K. et al. Anaerobic co-digestion process for biogas production: progress, challenges and perspectives. Renewable and Sustainable Energy Reviews, v. 76, p. 1485-1496, 2017.

HELLMAN, H. L.; VAN DEN HOED, R. Characterising fuel cell technology: challenges of the commercialisation process. International Journal of Hydrogen Energy, v. 32, n. 3, p. 305-315, 2007.

HELMS, H. et al. Electric vehicle and plug-in hybrid energy efficiency and life cycle emissions. In: INTERNATIONAL SYMPOSIUM TRANSPORT AND AIR POLLUTION, 18., 2010, Zurich. Annals [...]. Zurich: Empa, 2010.

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Pesquisa de Orçamento Familiar. Rio de Janeiro: IBGE, 2019. Available at: https://www.ibge.gov.br/estatisticas/sociais/educacao/9050-pesquisa-de-orcamentos-familiares.html. Accessed: Nov. 12, 2020.

______. Censo Agropecuário 2017. Rio de Janeiro: IBGE, 2017.

IEA – INTERNATIONAL ENERGY AGENCY. Technology Roadmap: low-carbon transition in the cement industry. Paris: Springer-Verlag, 2018. p. 66.

IRENA – INTERNATIONAL RENEWABLE ENERGY AGENCY. Rethinking Energy 2017: accelerating the global energy transformation. Abu Dhabi: Irena, 2017. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/IRENA_REthinking_Energy_2017.pdf. Accessed: Nov. 12, 2020.

INOVA – AGÊNCIA DE INOVAÇÃO DA UNICAMP. Nossa missão. [S.l.]: [s.d.]. Available at: https://www.inova.unicamp.br/sobre-a-inova/. Accessed: Nov. 14, 2020.

ISPA – INTERNATIONAL SOCIETY OF PRECISION AGRICULTURE. Precision Ag Definition. Illinois: Ispa, 2019. Available at: https://www.ispag.org/about/definition. Accessed: June 16, 2020.

ITC – UNIVERSITY OF TWENTE'S FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION. Satellite and Sensors Database. Enschede: ITC, 2019. Available at: https://webapps.itc.utwente.nl/sensor/default.aspx?view=allsensors. Accessed: Apr. 26, 2019.

IZO, A. Toyota confirma que Corolla será 1º carro com motor híbrido flex. Revista Auto Esporte, 17 abr. 2019. Available at: https://revistaautoesporte.globo.com/Noticias/noticia/2019/04/toyota-corolla-hibrido-flex-sera-fabricado-em-sao-paulo-e-chega-esse-ano.html. Accessed: Jan. 25, 2020.

JOHN, V. M. et al. Fillers in cementitious materials: experience, recent advances and future potential. Cement and Concrete Research, v. 114, p. 65-78, 2018.

JOSHI, S. B.; JANI, A. R. Design, development and testing of a small-scale hybrid solar cooker. Solar Energy, v. 122, p. 148-155, 2015.

KAMARUDIN, M. Z. F. et al. Review: direct ethanol fuel cells. International Journal of Hydrogen Energy, v. 38, n. 22, p. 9438-9453, 2013.

LAJUNEN, A.; LIPMAN, T. Lifecycle cost assessment and carbon dioxide emissions of diesel, natural gas, hybrid electric, fuel cell hybrid and electric transit buses. Energy, v. 106, p. 329-342, 2016.

LEONARD, E. C. Precision agriculture. In: WRIGLEY, C. W. (Ed.). Encyclopedia of Food Grains. 2nd ed. Maitland: Elsevier, 2015. v. 4, p. 162-167.

LIMA, R. R. Fabricação e estudo de um fogão solar à concentração mono e bifocal. 2018. Thesis (Bachelor of Mechanical Engineering) – Universidade do Rio Grande do Norte, Natal, 2018. Available at: https://monografias.ufrn.br/jspui/bitstream/123456789/6841/1/TCC_Rodrigo_Rodrigues_com_Ata.pdf. Accessed: Nov. 12, 2020.

MAES, W. H.; STEPPE, K. Perspectives for remote sensing with unmanned aerial vehicles in precision agriculture. Trends in Plant Science, v. 24, n. 2, p. 152-164, 2019.

MIRANDA, P. E. V. Processo de obtenção de suspensões aquosas para eletrodos de pilhas a combustível de óxido sólido e outros dispositivos eletrocatalíticos. Patent holder: COPPE/UFRJ – Coordenação dos Programas de Pós-Graduação de Engenharia da Universidade Federal do Rio de Janeiro (BR/RJ). Patent submitted by: Joubert Gonçalves de Castro. BR n. PI 0601210-8 A. Patent submitted: Mar. 17, 2006. Patent granted: Nov. 27, 2007. Rio de Janeiro, 2007.

MIRANDA, P. E. V.; CARREIRA, E. D. S. Sistemas inteligentes de gerenciamento de energia para veículos elétrico e elétrico-híbrido com conexão bidirecional, sistema inteligente de gerenciamento de energia para um gerador de energia, método para gerenciar energia em um sistema inteligente de gerenciamento de energia e método para controlar o funcionamento de um gerador de energia. Patent holder: Coordenação dos Programas de Pós-Graduação de Engenharia da Universidade Federal do Rio De Janeiro, Tracel Veículos Elétricos Ltda. Patent submitted by: Dannemann, Siemsen, Bigler & Ipanema Moreira. BR n. BR 102012027618-6 A2. Patent submitted: Oct. 26, 2012. Patent granted: Sept. 20, 2016. Rio de Janeiro, 2016.

MIRANDA, P. E. V.; ICARDI, U. A. Sistema de teste para pilhas a combustível de alta temperatura de operação multicombustível, o qual permite a utilização direta de combustíveis carbonosos sem promover a deposição de carbono nos elementos de passagem de combustível. Patent holder: Oxiteno S.A. Indústria e Comércio, Energiah Participações e Negócios Ltda, Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia – COPPE/UFRJ. BR n. BR 102015021820-6 A2. Patent submitted: Sept. 4, 2015. Patent granted: Mar. 14, 2017. Rio de Janeiro, 2017.

MIRANDA, P. E. V.; TORRES, S. O. A. Processo para o aproveitamento da energia cinética de veículos elétricos híbridos e armazenador de energia através de ar comprimido. Patent holder: Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia – COPPE/UFRJ. BR n. PI0801587-2 A2. Patent submitted: May 21, 2008. Patent granted: Feb. 1, 2011. Rio de Janeiro, 2011.

MIRANDA, P. E. V.; VENANCIO, S. A.; MIRANDA, H. V. Method for the direct oxidation and/or internal reforming of ethanol, solid oxide fuel cell for direct oxidation and/or internal reforming of ethanol, catalyst and multifunctional electrocatalytic anode for direct oxidation and/or internal. USA n. US 9431663 B2. Patent submitted: June 11, 2016. Patent granted: Aug. 30, 2016. Rio de Janeiro, 2016.

MOLIN, J. P.; AMARAL, L. R.; COLAÇO, A. F. Agricultura de precisão. 1. ed. São Paulo: Oficina de Textos, 2015.

MUNOZ, F. Global sales of AFVs surpassed the million mark during Q1 2018. Jato, 2018. Available at: https://www.jato.com/global-sales-afvs-surpassed-million-mark-q1-2018/. Accessed: Jan. 25, 2020.

MYERS, N. et al. Biodiversity hotspots for conservation priorities. Nature, v. 403, p. 853-845, 2000.

NKRUMAH, J. D. et al. Relationship of feedlot feed efficiency, performance, and feeding behaviour with metabolic rate, methane production, and energy partitioning in beef cattle. Journal of Animal Science, v. 84, pp. 145-158, 2006.

OLIVEIRA, L. G. S.; NEGRO, S. O. Contextual structures and interaction dynamics in the Brazilian Biogas Innovation System. Renewable and Sustainable Energy Reviews, v. 107, p. 462-481, 2019.

ONG, B. C.; KAMARUDIN, S. K.; BASRI, S. Direct liquid fuel cells: a review. International Journal of Hydrogen Energy, v. 42, n. 15, p. 10142-10157, 2017.

PARA SUBSTITUIR botijão de gás, pesquisadores brasileiros fabricam fogão solar. Portal Solar, 5 jul. 2018. Available at: https://www.portalsolar.com.br/blog-solar/energia-solar/para-substituir-botijao-de-gas-pesquisadores-brasileiros-fabricam-fogao-solar.html. Accessed: Feb. 10, 2020.

PEREIRA, P. M. C. C.; VICENTE, A. F. R. B. Meat nutritional composition and nutritive role in the human diet. Meat Science, v. 93, n. 3, p. 586-592, 2013.

PINARES-PATINO, C. S. et al. Heritability estimates of methane emissions from sheep. Animal, v. 7, p. 316-321, 2013.

PNUD – PROGRAMA DAS NAÇÕES UNIDAS PARA O DESENVOLVIMENTO; FJP – FUNDAÇÃO JOÃO PINHEIRO; IPEA – INSTITUTO DE PESQUISA ECONÔMICA APLICADA. Renda per capita municipal. In: PNUD – PROGRAMA DAS NAÇÕES UNIDAS PARA O DESENVOLVIMENTO; FJP – FUNDAÇÃO JOÃO PINHEIRO; IPEA – INSTITUTO DE PESQUISA ECONÔMICA APLICADA. Atlas do Desenvolvimento Humano no Brasil. Brasília: Pnud; FJP; Ipea, 2013.

RAJÃO, R. et al. The rotten apples of Brazil's agribusiness. Science, v. 369, n. 6501, p. 246-248, 2020.

RIBASKI, J. Plantios mistos. Agência Embrapa de Informação Tecnológica, Brasília, 2019. Available at: https://www.agencia.cnptia.embrapa.br/gestor/eucalipto/arvore/CONT000h0181hfe02wx7ha07d3364p6fl1d0.html. Accessed: Aug. 6, 2020.

RIBEIRO, K. S. et al. Tecnologias disruptivas de baixo carbono para setores-chave no Brasil: Relatório Especial do Painel Brasileiro de Mudanças Climáticas. Rio de Janeiro: Fundo Verde, 2017.

SAMARAS, C.; MEISTERLING, K. Life cycle assessment of greenhouse gas emissions from plug-in hybrid vehicles: implications for policy. Environ. Sci. Technol., v. 42, p. 3170-3176, 2008.

SARRUF, B. J. M. et al. Ceria-Co-Cu-based SOFC anode for direct utilisation of methane or ethanol as fuels. International Journal of Hydrogen Energy, v. 45, n. 8, p. 5297-5308, 2020.

SCRIVENER, K. L.; JOHN, V. M.; GARTNER, E. M. Eco-efficient cements: potential economically viable solutions for a low-CO2 cement-based materials industry. Cement and Concrete Research, v. 114, p. 2-26, 2018.

SEBRAE – SERVIÇO BRASILEIRO DE APOIO ÀS MICRO E PEQUENAS EMPRESAS. Biblioteca de legislação do biogás. DataSebrae, 2020. Available at: https://datasebrae.com.br/biblioteca-legislacao-biogas/. Accessed: Apr. 30, 2020.

______. Missão. [S.l.]: [s.d.]. Available at: https://m.sebrae.com.br/sites/PortalSebrae/canais_adicionais/conheca_estrategia. Accessed: Aug. 6, 2020.

SHE – SOLAR HOUSEHOLD ENERGY. 2015-2016 Solar Stove Adoption Project in Tilori Haiti Evaluation Report. [S.l.]: SHE, 2017. Available at: http://www.she-inc.org/wp-content/uploads/2014/03/2017-02-Solar-stove...Tilori_Eval-Rpt_to-SELF_SHE.pdf. Accessed: Nov. 12, 2020.

SIBIYA, B. I.; VENUGOPAL, C. Solar Powered Induction Cooking System. Energy Procedia, v. 117, p. 145-156, 2017.

SILVA, J. M.; RYLANDS, A. B.; FONSECA, G. A. B. The Fate of the Amazonian Areas of Endemism. Conservation Biology, v. 19, n. 3, p. 689-694, 2005.

SNIC – SINDICATO NACIONAL DA INDÚSTRIA DO CIMENTO. Roadmap Tecnológico do Cimento: potencial de redução das emissões de carbono da indústria do cimento brasileira até 2050. Rio de Janeiro: SNIC, 2019.

TNO. Phyllis2 – ECN Phyllis classification. [S.l.], 2020.

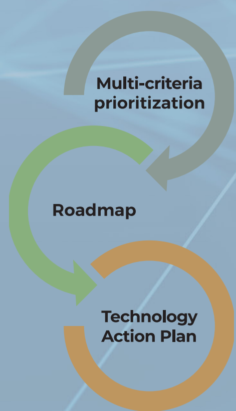
UHLIG, A. Lenha e carvão vegetal no Brasil: balanço oferta-demanda e métodos para a estimação do consumo. 2008. Tese (Doutorado em Energia) – Universidade de São Paulo, São Paulo, 2008. Available at: https://teses.usp.br/teses/disponiveis/86/86131/tde-14052008-113901/publico/UHLIG_Tese1.pdf. Accessed: Nov. 12, 2020.

UNITES STATES. US Department of Energy. Fuel cells. Washington: DOE, 2020.

VENÂNCIO, S. A.; MIRANDA, P. E. V. Direct utilization of carbonaceous fuels in multifunctional SOFC anodes for the electrosynthesis of chemicals or the generation of electricity. International Journal of Hydrogen Energy, v. 42, n. 19, pp. 13927-13938, 2017.

ZHANG, X. et al. How well do deep learning-based methods for land cover classification and object detection perform on high resolution remote sensing imagery? Remote Sensing, v.12, n. 3, p. 417, 2020.

Appendix


Multi-criteria prioritization
Roadmap
Technology Action Plan

APPENDIX I – BARRIERS TO THE DEVELOPMENT AND/OR DIFFUSION OF THE PRIORITIZED TECHNOLOGIES

TYPE OF BARRIER	DESCRIPTION
FLOATING PHOTOVOLTAIC SOLAR ENERGY	
Technical	Lack of an inventory of the potential of the energy source: In Brazil, there is no map of the potential for installing floating solar plants in hydroelectric reservoirs. In addition to assessing the solar resource, this type of inventory should take into account technical restrictions, such as the minimum depth of reservoirs for installing solar plants, as well as restrictions on other priority uses of reservoirs, which may include navigation, water supply, tourism, leisure, fishing and environmental preservation, among others. These factors limit the area available for floating solar projects in HPP reservoirs. The absence of this data makes it difficult to select the best locations for implementing projects, hindering the development of the technology in Brazil.
	Lack of knowledge of the environmental impacts of projects: Due to the limited number of projects installed in Brazil, and the specific local conditions of each project, little can be concluded concerning the environmental impacts of floating solar technology in reservoirs. An example is covering the water surface with solar panels (depending on the size of the project), which limits the amount of light penetrating the water column and the exchange of heat between the reservoir and the atmosphere. Moreover, in some cases, it can prevent undesired consequences such as algae proliferation in reservoirs, but it can also negatively affect the aquatic habitat and its biodiversity. Thus, there is no consensus on the percentage of reservoir surface area that could be covered with panels.
	Difficulty anchoring panels in large reservoirs and/or with significant variations in water level: A challenge for floating solar plant anchoring systems in HPP reservoirs is adaptation to the size of the reservoir, which can be thousands of square kilometers in some cases, resulting in large installations and at great distances from reservoir banks. Anchoring systems must also resist physical efforts, such as winds and currents, and be able to adapt to variations in reservoir water levels, which may vary due to HPP operations or climatic conditions such as precipitation and evaporation.
	Difficulty maintaining the angle of panels: Due to the movement of the water surface, it is difficult to control the angle of solar panels. Since the floating structure is not static, solar tracking technology is generally not used in floating solar plants, limiting efficiency.
	Technological maturity level of floating inverters in large reservoirs: Depending on the size of the reservoir and distance of the floating solar plant to the bank, it may require installing inverters on floating platforms (instead of on land) to reduce losses in electricity transmission. However, in addition to being more expensive, the technology lacks technological maturity.

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TYPE OF BARRIER	DESCRIPTION
Economic and market	Few suppliers of floating solar technology: The market for floating structures for solar panels, inverters and transformers is dominated primarily by two large-scale suppliers in the world: Ciel & Tierre and Sungrow. Only Ciel & Tierre is present in Brazil, through its licensed representatives: Sunlution and F2B.
	Lack of competitiveness compared to solar power generation on land: The main motive for implementing solar plants on water surfaces in other countries is the low availability of land and its high cost. However, this is not a problem in Brazil, where the areas with the greatest solar potential are located in the arid northeast region. Thus, the higher cost of floating solar energy, compared to conventional energy, is not compensated, which translates into a lack of competitiveness of the energy source in the Brazilian energy market (if there are no other incentives for its adoption).
	High capital costs: The capital costs of floating solar are higher than solar energy on land, mainly due to the cost of floats, the anchoring system and the electrical components such as floating inverters and underwater cables (when used).
Regulatory and institutional	Lack of clarity in the environmental licensing process: As it is a new technology in Brazil, with poorly understood environmental impacts, the licensing process, including environmental studies for the installation of floating solar plants in reservoirs, is not yet adequately defined. Conventional solar energy projects, which generally have few impacts to their surroundings, are licensed according to the size of the project. In most cases, the procedure is quite simple and fast. The lack of definition in the licensing process can result in delays and risks for projects.
	Lack of clear reservoir management obligations: There is a degree of uncertainty with respect to rights and obligations for the management of floating solar plants in multiple-use reservoirs, which results in regulatory risks that may hinder the development of the energy source in certain locations.
	Lack of regulatory framework for energy contracting: The combination of floating solar and hydroelectric plant reservoirs offers complementary benefits for both. However, it is necessary to define rules for contracting the electricity produced by hybrid systems (a discussion that was recently initiated by ANEEL and EPE). Another issue is energy auctions, which should address floating solar systems as solar plants or as hybrid systems (HPP and solar), and define the rules for competition in the regulated energy market.
Cultural and training	Ignorance of the technology and its benefits: As it is a new technology in Brazil, there is some degree of hesitancy to its adoption due to perceived high costs and operation complexity. In addition, given its lack of competitiveness compared to other renewable energy sources (including solar on land), the current high costs outweigh the advantages. Part of the rejection stems from a lack of knowledge of the benefits of the technology and the still poorly understood environmental impacts that require further study in Brazil. Furthermore, the lack of an inventory of the source's potential in Brazil also undermines interest in the technology.

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TYPE OF BARRIER	DESCRIPTION
FLEX HYBRID VEHICLES	
Technical	Lack of technological standards: There is a wide variety of battery, electric motor and converter technologies today. Automotive sector companies produce models with different types of equipment, demonstrating that there is no preference for any specific technology. This indicates that, even though these components are widely used outside the automobile industry, there is still room for technological development of these components. Given the variety and combinations of these technologies, there is a need for benchmarks.
	Technology maturity level of power transistors: These semiconductors are necessary for converting different voltage waveforms and controlling the flow of electrical energy, which are essential for the conversion and reconversion of the gasoline engine to the electric motor. This component is still being improved and there is no optimal technology (and it is not produced in Brazil).
Economic and market	Low local content in vehicle components: The national automaker that produces a hybrid flex vehicle in Brazil imports a good number of the components, including the hybrid assembly (produced in factories abroad).
	Supply shortage: There is a shortage of hybrid flex vehicles due to manufacturing capacity not being able to keep up with consumer demand.
	High final consumer price: Flex hybrid vehicles have gone through four of the five technological development phases (research and development, prototype, pilot project and, currently, the commercialization phase), lacking only the maturation and competitiveness phases. This results in high vehicle prices that only the wealthier social classes can afford.
	High level of investment by automakers: Modernizing and converting a factory to produce flex hybrid vehicles in Brazil requires a high level of investment.
	Potential loss of jobs in traditional auto companies: Although the workforce can be reallocated to produce hybrid flex vehicles; in the short term, part of the workforce may not be absorbed due to the lack of qualifications for assembling new vehicles.
Regulatory and institutional	Lack of legal framework and specific lines of financing for electric vehicles: The insertion of electric vehicles faces regulatory gaps that result in uncertainties for investors in electric mobility. In addition, there are no specific mechanisms for financing flex hybrid vehicles.
Cultural and training	Ignorance of the benefits of the technology: As it is a new technology in the country, the public is not aware of the potential benefits, such as reducing greenhouse gas emissions and local pollutants. There are also uncertainties about vehicle autonomy and maintenance costs.

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TYPE OF BARRIER	DESCRIPTION
ETHANOL FUEL CELL ELECTRIC VEHICLES	
Technical	Lack of consensus on the optimal energy conversion technology: The process of using ethanol directly in the fuel cell is widely discussed in the literature and by Brazilian researchers. However, there is no consensus on the type of direct ethanol fuel cell or the best choice of components for the catalyst. There is a need for further studies and improvements in this process, such as fuel crossover and catalyst damage. As it is still a developing technology, there is no optimal specification.
	Lack of technology standards: There is a wide variety of technologies for batteries, electric motors and converters. Different automotive sector companies end up developing models with different types of equipment. Although these components are used outside the automobile industry, this indicates that there is still scope for the technological development of these components, given the number of existing combinations between these technologies. A benchmark is required.
	Lack of local content and maturity level of power transistors: These semiconductors are necessary for converting different voltage waveforms and controlling the flow of electrical energy, which are essential for the conversion and reconversion of the gasoline engine to the electric motor. This component has not yet reached maturity and there is no consensus on the optimal technology. Furthermore, the technology is not produced in Brazil.
Economic and market	Dependence on the international market: Development of the hydrogen fuel cell in the international market cannot be directly applied to the implementation of direct ethanol fuel cells.
	Low level of technological development: The direct ethanol fuel cell vehicle is in the third stage of technological development (proof of concept of critical functions in experimental stage). Thus, there is a lack of solid technological development to demonstrate the effectiveness, usability and diffusion of the technology.
	High final consumer price: Given the lack of production of fuel cells in Brazil, the cost of imported components is expected to be high. This high cost is a barrier to purchasing vehicles, except for wealthier social classes.
Cultural and training	Ignorance of the benefits of the technology: As it is a developing technology, the population is unaware of the potential benefits.

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TYPE OF BARRIER	DESCRIPTION
AGRICULTURAL AND AGRO-INDUSTRIAL WASTE FOR ENERGY GENERATION	
Technical	Heterogeneity of substrates: Given the heterogeneous nature of the substrates, they must be characterized to determine the appropriate pre-treatment technologies for different types of waste.
	Lack of gravimetric waste data: The lack of gravimetric waste data in different regions of the country makes it difficult to map and size the market and carry out feasibility studies.
	Inadequate definition of pre-treatment technologies: Due to the heterogeneity of raw materials (waste) for the co-digestion process, studies are needed to identify the appropriate pre-treatment technologies for the different kinds of waste.
Economic and market	Seasonal availability of agricultural waste: The seasonal availability of waste discourages financing for alternative uses and makes it difficult to establish a market for biodigestion products. A constant and predictable supply of the waste is necessary to make projects viable and ensure commercialization contracts.
	Lack of a market for biogas: There is no market for biogas in Brazil. The absence of financing and a specific regulatory framework for biogas are factors that, in many cases, make biodigestion projects unfeasible, except for electricity or biomethane production (which have lower investment costs). Some existing financing lines may even be suitable for biogas projects, but some particularities, such as the requirement of guarantees for financing, make access to credit difficult.
	Lack of a market for biomethane in the transport sector: The development of the biomethane market for use in heavy vehicles has potential in the country. However, the development of this market requires large-scale production of the biofuel and the adaptation of dual diesel-biomethane engines in the Brazilian transport fleet.
	Limited value of biomethane: The lack of alternatives for the commercialization of biomethane limits its value to the price defined by the concessionaires that distribute natural gas. In the absence of negotiation, this can make biodigestion projects for the production of biomethane unfeasible.
	High capital, operating and maintenance costs: The main economic barrier is associated with high capital (CAPEX) and operating and maintenance (OPEX) costs. These costs, associated with both biodigesters and waste pre-treatment technologies, discourage investments and hinder the transfer of knowledge of the technology to train local labor. The lack of a consolidated market for biodigestion products imposes the need to import equipment, resulting in high investment costs for projects.
Regulatory and institutional	Lack of regulations and exclusive financing lines: The lack of a specific regulatory framework and exclusive financing lines is the main institutional barrier. In view of the significant potential of energy generation from waste to replace fossil fuel energy sources, these instruments could support strategic and integrated implementation, stimulating new projects, investments and knowledge.
Cultural and training	Unsuccessful biodigestion projects: In the 2000s, a number of biodigesters were installed in the country, motivated by the carbon credit market created by the Clean Development Mechanism (CDM) of the Kyoto Protocol. However, the global economic crisis (and the subsequent fall in carbon credit values) affected the viability of projects in the medium and long term. These failures resulted in investor uncertainty in the sector and reduced the attractiveness of new projects. In addition, the lack of expertise in the production of energy from agricultural waste is also a critical barrier that needs to be overcome.

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TYPE OF BARRIER	DESCRIPTION
SOLAR INDUCTION STOVES	
Technical	Technology maturity level: There is no field implementation of a photovoltaic system with solar induction stoves in Brazil, which restricts testing to the operational demonstration environment.
Economic and market	Lack of technology value chains: In rural regions in Brazil, there are no value chains for installing and maintaining solar stoves and photovoltaic systems.
	High cost of additional equipment for the induction stove: The photovoltaic system and solar induction stove equipment has a prohibitive cost for low-income families, who generally use firewood for cooking.
Cultural and training	Resistance to change in cooking behavior: Families that use wood stoves are used to cooking food slowly, which hinders the adoption of induction stoves in households.
	Ignorance of the benefits of the technology: A large part of the population is still ignorant of the benefits of implementing photovoltaic systems in buildings.
	Lack of training for the installation and maintenance of systems: In rural regions, such as the semiarid Northeast region, there is a lack of qualified labor to install and maintain photovoltaic systems and solar induction stoves.

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TYPE OF BARRIER	DESCRIPTION
INNOVATIVE MATERIALS FOR CEMENT	
Technical	Low reactivity of additions: Limestone filler has low reactivity, acting as a diluent for cement when added in ratios greater than 5%. This is compensated by increasing clinker grinding, which must be done separately when grinding the filler, so that the particle sizes remain compatible.
	High level of energy emissions in clay calcination: The calcination of clay, while not producing process emissions, requires a considerable amount of thermal energy, corresponding to about 70% of the energy required to calcinate clinker. This limits the GHG mitigation potential of calcined clays as a substitute for clinker, compared to the other additions evaluated.
Economic and market	Reduction in the availability of industrial residues and by-products currently used in the cement industry: Experts in the cement sector expect a reduction in the supply of materials traditionally used as additions for cement. This market barrier affects the future use of granulated blast furnace slag and fly ash, making the supply of these raw materials vulnerable in the value chain.
	Calcination furnaces limit the potential of using calcined clays: Given the high capital costs for purchasing furnaces for clay calcination, most of the equipment for this purpose in Brazil today is old cement calcination furnaces that were repurposed. There are practically no furnaces purchased by investors for the sole purpose of clay calcination. Thus, despite being an abundant raw material in Brazil, the use of clays in the cement industry is conditioned to the availability of a nearby calcination furnace, making this raw material a critical gap in the value chain.
	Ignorance of the availability of supplementary cementitious materials: There are no studies that map the availability of granulated blast furnace slag, coal ash, limestone and calcined clays in Brazil, which limits the use of these materials to replace clinker in cement production.
	Lack of production arrangements for the production of new cements and technical-economic feasibility studies: Little research has been carried out in Brazil aimed at testing the production of cements with a lower clinker content, which makes it difficult to establish new production arrangements.
Institutional and regulatory	Ties to international standardization: Standardization in the sector follows the guidelines of the main international institutions (ASTM and EN), which are essentially prescriptive and dictate the composition of cements for producers. This limits the ability to exploit locally available raw materials to produce cements of equal (or higher) quality, compared to cements determined by current regulations.
Cultural and training	Low qualification level of small contractors: Traditional Portland cement is forgiving and easy to use when making concrete and mortar, even for non-professional users. Thus, technological innovations in the sector that demand greater control in the ratios of materials for mixing concrete face this cultural and information barrier among small building contractors (who tend to use the fixed ratios they are accustomed to).
	Conservatism in the construction sector: The construction sector is characteristically conservative and skeptical of technological innovations, given the potential consequences that the failure of a structural material can have. Thus, the acceptance of technological changes in the cement market is a challenge that reverberates across the value chain and, especially, with end users.

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TYPE OF BARRIER	DESCRIPTION
INDUSTRY 4.0	
Technical	Low performance in the development of hardware, software and analytics: Important skills in technology areas in Brazil are still lacking in automation, Big Data and internet infrastructure markets, which are key elements of these technology platforms.
	Lack of interoperability standards and data security: Another technological bottleneck is the need to customize existing solutions for customers in different sectors, which requires the definition of communication standards. Moreover, data security for industrial competitiveness is one of the main challenges for consolidating industry 4.0.
	Limited broadband and mobile network infrastructure: The basic infrastructure of the entire 4.0 technological apparatus is the national telecommunication system. Thus, the limited broadband and mobile network infrastructure is an obstacle, since the flow of data is essential for production operations in industry 4.0.
Economic and market	Lack of digital integration among companies in production chains: The digital integration of companies in production chains is essential for efficiency gains and relations between customers and suppliers in industry 4.0. This requires not only the adaptation of existing processes in Brazil, but also the development and incorporation of new hardware and software technology.
	Concept not disseminated: Although some companies and startups currently employ circular business models that incorporate 4.0 technologies, there is still a lack of knowledge of the concept in various industrial segments and spheres. Industry 4.0 is still quite new and not yet known in Brazil. This lack of knowledge can be seen in the education system, from basic to higher education, and results in few professionals trained to think in a methodical and systemic manner to redesign products, circular processes and, especially, adopt innovative circular business models.
	Insufficient workforce: Another market barrier is lack of a sizable, qualified and trained workforce.
	Uncertain return on investment: Although promising, there are many uncertainties with respect to return on investment in industry 4.0 due to the lack of scale of technologies, high capital costs and the long period to realize return on investment.
Regulatory and institutional	Outdated or obsolete regulations: For the transformation to industry 4.0, there are several areas that require changes to regulations, especially those that address data protection and security, personal and non-personal data rights, contractual information, legal responsibility, intellectual property, product security, civil rights and obligations, labor, taxation, market competition and antitrust. In Brazil, many regulations are inadequate for the 4.0 ecosystem, since they were approved in another production environment and do not reflect current trends in technology. In general, there is a lack of institutional support and a clear and strategic direction for industry 4.0 in the country, which is reflected in the regulatory framework.
	Lack of policies for technology, commercial and knowledge sharing: A barrier in the public sphere is the lack of investment in training to create a highly qualified workforce. Another challenge is the lack of industry policy instruments capable of enabling and encouraging technological and commercial exchange with other countries for access to knowledge.
Cultural and training	Lack of professional training policies: There is a lack of knowledge on digital technologies and their benefits. There is a need to disseminate this knowledge through a revision of curricula in education and the promotion of industry fairs, seminars and congresses on industry 4.0. In short, there is a need to invest in human resources training for industry 4.0.

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TYPE OF BARRIER	DESCRIPTION
PRECISION AGRICULTURE	
Technical	Lack of connectivity, interfaces and data security: The low level of connectivity between technologies is a cross-sectoral barrier in the PA value chain. Interface is hindered by programs built in open source or different programming languages. There is also the problem of incompatibility of equipment connectors, especially when adaptations are made to machinery or farm implements not designed for PA. In addition, the risk of access and violation of automated equipment creates uncertainty and can lead to significant losses. Finally, internet access must be improved in rural regions, as well as cloud computing with adequate data security.
	Inaccessible autonomous systems: This is a cross-sectoral barrier especially hinders decision making and the control of indicators. There is some equipment on the market with this technology, but it is usually expensive, especially for small producers.
	Lack of national technology: This barrier is seen in the cost of equipment and poorly adapted machinery for the diversity of Brazilian agriculture. Bearing in mind that PA has high capital costs for the producer, it is important to foster the development of national equipment to provide a more affordable alternative to imported technology.
	Limited public data off the farm: With respect to databases, in most regions of Brazil, available data is limited in scale and not updated. The network of climatic and environmental data is another problem area, as many areas of the country have few weather stations, limiting the quality of analysis.
	Lack of accuracy in digital image processing: Remote sensing and digital image processing have evolved considerably in recent years. However, these are still barriers in PA, especially for image classification. Classification is important for determining land use, differentiating different crops and identifying pests and diseases in the field quickly and accurately. New deep learning techniques have emerged as facilitators, with improvements in classification. However, they are not perfect, and development and better applications in agriculture are required.
Economic and market	High cost of modern equipment: The high cost of equipment is one of the main barriers to the diffusion of PA in Brazil, since the producer is often unable to purchase a complete system due to the high purchase and system maintenance costs. Complete PA systems are complex and include machinery, equipment and implements adapted for PA, software and even internet infrastructure and solutions for transferring data in agricultural areas.
Regulatory and institutional	Lack of specific policies to promote the green economy: Payment for Environmental Services (PES) and a carbon credit market could encourage producers to adopt PA, which would favor more sustainable agriculture.
	Lack of specific regulations to encourage the adoption of PA: There is no specific legislation (or entities) to encourage PA. The CBAPD is an exception, though it does not have the objective of creating the Network.

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TYPE OF BARRIER	DESCRIPTION
Cultural and training	Low perceived value of PA by farmers: The vast majority of farmers are aware of PA and its benefits. However, the variable application of inputs does not always increase crop yields, though it does provide constant yields while reducing input costs. PA allows farmers to obtain greater profits through better management and the application of focused, more appropriate and reduced chemical interventions, which also reduce environmental impacts. Thus, producers may believe they can obtain greater profits with the implementation of PA, but feel the increase in profits is not worth the increase in work.
	Changes in the agricultural management model: PA requires a change in the management model adopted on most Brazilian properties and can increase the amount of work for agricultural managers. Every change results in some inconvenience, and it can be even more difficult when there is low perceived value. In addition, there is a need for ongoing investments in training for technicians and producers.
	Lack of practical and intuitive tools: For the diffusion of PA, it is necessary to create practical and intuitive tools to implement PA technology, without increasing work for agricultural managers.
	Lack of training: The high cost to implement PA technology is one of the main barriers to the diffusion of PA. However, there are cases where the producer has access to PA equipment, but due to the lack of technical training, the technology is not fully utilized.

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TYPE OF BARRIER	DESCRIPTION
GENETIC IMPROVEMENT IN BEEF CATTLE	
Technical	Lack of standardization for data collection procedures: Procedures for the collection of genetic material are not standardized and widely adopted. Data collection, even for simple measurement characteristics (such as body weight), is not standard. There are differences with respect to fasting before weighing, types of scales and measurement age. Furthermore, data collection procedures for more complex characteristics (such as feed efficiency) still lack standardization for the animal adaptation period to the facilities and diet, test period, diet composition and methodology for calculating the characteristics.
	Lack of integration and agility between genetic improvement programs: The wide variety of tools for data collection and storage on farms also makes it difficult to integrate the data transfer steps and ensure agility between genetic improvement programs. While there are many tools for collecting and storing data, genetic evaluations in most programs are carried out using the same imported software, with a dependency on imported technology.
Economic and market	Additional costs when commercializing genetic material: One of the ways to transfer superior genetic material between selection farms and commercial farms is through the sale of young bulls. A significant percentage of the sale of bulls takes place through auctions, where an intermediary agent (the auction company) is responsible for attracting customers and carrying out negotiations. The auction houses have large portfolios of customers in the meat producing regions, which helps to increase the value and demand for superior genetic material. On the other hand, they normally charge buyers a rate of 8% on the sale price.
	Additional costs on the sale of bulls: There are costs for vendors of genetic material and bulls, such as freight, advertising, transaction costs and the rental of enclosures. Recently, vendors have used other forms of marketing, such as direct sales on the farm. Despite reducing sales-related costs, this strategy has not allowed for the sale of 100% of the available bulls, and the prices are lower than auction prices.
	Differences between production systems: Directly related to the lack of standardized data collection and integration between stakeholders, the differences in production systems makes the genetic improvement process more expensive. The vast size of Brazil makes the adoption of production system standards complex. Progress must be made towards selecting species that are better adapted to the edaphoclimatic conditions of the different Brazilian biomes.
Regulatory and institutional	Lack of a regulatory framework for minimum standardization of genetic improvement: There are no regulatory norms that establish minimum standards of genetic potential for the commercialization of bulls used for breeding (except for the commercialization of semen). Due to this regulatory gap, bulls with unknown (or inferior) genetic potential have appeared at lower prices (compared to good quality genetic material). This undermines the diffusion of genetic improvement and prevents the production chain from capitalizing on the benefits of the technology.
Cultural and training	Ignorance of the economic value of animal characteristics: On selection farms and commercial farms, some breeding animals are used with great frequency. This may be due to the supplier's business strategy, or because the bull was a champion in an agricultural exhibition or placed first in a group of bulls (i.e. results of genetic evaluation). This results in a reduction in genetic variability in the population and can hamper the evolution of genetic improvement programs. This lack of knowledge of the economic value of animal characteristics results in the use of subjective selection criteria that do not address the needs of users of genetic material. This results in selecting bulls that are unsuitable for a given production system and compromising genetic benefits and economic returns.

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TYPE OF BARRIER	DESCRIPTION
SILVICULTURE AND GENETIC IMPROVEMENT OF NATIVE SPECIES	
Technical	Low level of confidence among entrepreneurs due to insufficient technological content: The selection of appropriate species for intended uses and the availability of genetic material resistant to pests and diseases are essential to achieving financial gains for entrepreneurs. This is essential to ensure interest in the cultivation of native species. The lack of other production factors, such as cultivation technologies, silviculture treatments, management and exploitation, which are currently poorly exploited in Brazil, reduces the level of confidence of entrepreneurs. This underscores the need for silviculture studies to ensure the quality and productivity of selected genotypes to satisfy market demands.
	Lack of policies to promote research: In 2006, the National Silviculture Plan for Native Species and Agroforestry Systems (PENSAF) was launched. The objective of the program is to create favorable conditions for the use of native forest species and agroforestry systems for commercial production purposes. Among the specific objectives of the Plan is the implementation of a research and development program aimed at generating knowledge and new technologies to improve the different production systems using native forest species. However, to date, these objectives have not been fully achieved and continue to represent an important barrier in the sector.
Economic and market	Rejection of juvenile wood produced in native species silviculture systems: The age of the tree may limit (but not prevent) the uses of its wood, though, at present, there is rejection of juvenile woods. This phenomenon results from natural variations in the biological process of wood formation. In young trees, such as those produced in silviculture systems, there is a higher ratio of juvenile wood to adult wood. The wood of these trees has variations in the anatomical, physical and chemical make up, which result in internal variations of the wood, especially in the radial direction. There are also variations between species with respect to the transition age from juvenile to adult wood. Genetic improvement and, importantly, appropriate technologies for primary processing and wood drying are able to minimize the effects of radial variation on the production of solid wood.
	High implementation costs of forest improvement programs: These improvement programs require large investments for their implementation, since, after the selection of the species, it is necessary to study various populations and individuals. These high costs hinder the diffusion of silviculture with genetic improvement of native species. However, in the long run, these costs are largely offset by gains in productivity and in the superior quality of wood and non-wood products.
	Long-term gains in productivity: The reproductive cycles of tree species are relatively long. This makes it difficult to produce mature stands for selection within the species of interest and, consequently, the genetic gains in productivity and quality of wood and non-wood products are slow and require decades of study.

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TYPE OF BARRIER	DESCRIPTION
Regulatory and institutional	Complexity of environmental legislation: This barrier arises from inconsistencies in the legislation that determine the need for a Document of Forest Origin (DOF), counter to the environmental legislation of some states.
	Difficulty accessing credit: In 2016, the Brazilian Forestry Service and the Ministry of Environment released the Forest Financing Guide. This document describes the different lines of credit for forestry projects with native species, including PRONAF Forests, and other credit programs (such as the BNDES - Climate Fund Program and Subprogram: Native Forests with support for forest planting with native species for the purposes of timber and non-timber production; and FCO VERDE - Nature Conservation). However, in order to use these credit lines for native species forestry projects, changes and modifications to the credit granting rules are necessary, especially with respect to repayment terms, grace periods and guarantees, considering the production cycle period of native species for the production of logs with sufficient diameter for a good yield in primary wood processing is much greater than those defined by the financing sources in the forestry financing guide. The guidelines are only compatible with the forestry projects using fast-growing exotic species. This inconsistency makes it impossible rural producers to obtain credit to invest in silviculture with native tree species.
	Lack of confidence among entrepreneurs: As projects involve long-term financial returns, there is a fear that investments are vulnerable, given that state environment policies may change in this period. In addition, there is also the belief that industrially synthesized products may replace wood in the future.
Cultural and training	Difficulty planning activities and lack of knowledge of public and private support mechanisms: These barriers stem from the lack of technical assistance and training in silviculture with native species for technicians and farmers. Technical assistance and training for rural producers, in addition to passing on knowledge about cultivation, management and forest exploitation, should also include information on public support mechanisms and, especially, commercialization.

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TYPE OF BARRIER	DESCRIPTION
MIXED PLANTING SILVICULTURE FOR RESTORATION	
Technical	Difficulty accessing equipment: The high cost and difficulty to access equipment for mixed planting silviculture are barriers to the development of the technology.
	Lack of studies and reported results: There are few studies on the different agroforestry systems and mixed planting silviculture to technically support actions in the field.
	Lack of investment in research on mixed planting silviculture: The lack of investment in research on mixed planting silviculture for restoration hinders its diffusion.
Economic and market	Dependence on large scale production: The implementation of mixed planting silviculture for restoration is penalized by the small production scale of a given product and high fixed costs, which often make the development of a production chain unfeasible.
	High cost of inputs, transport and implementation of mixed planting systems: The high implementation costs are due to several factors. The minimum necessary production capacity and distance from consumer centers imply a cost-benefit ratio that often makes projects unfeasible. Freight, depending on the product and location, has considerable financial impacts on the final price of the product due to logistics. The need to purchase more than one species for planting often involves purchases in different nurseries, and seedlings require care and maintenance for at least 3 years before planting. Despite the diminishing costs, the plantation has a high initial and total cost. Plantations areas with difficult topography (without the option of mechanization and lacking infrastructure to meet the demands of Agroforestry Systems) have higher costs due to poor efficiency.
	Lack of labor in rural areas: In recent years, the exodus and aging of the rural workforce have greatly reduced the availability of labor on rural properties. Mechanization and difficulty in obtaining formal work in the field are also factors that contribute to the lack of labor. When labor is available, it tends to be unskilled.
Regulatory and institutional	Bureaucratic federal, state and municipal procedures: Bureaucratization, as well as the decline in investments for monitoring, hinder the implementation of the Forest Code, thus impacting the diffusion of technology.
	Forest replanting with native species: The Brazilian Forest Code establishes the preferential use of native species for forest replanting, as determined by the Sisnama body for the use of raw materials (Art. 33, § 4). This determination undermines the development of mixed planting silviculture with exotic species.
	Limitation on the planting of exotic species on properties of up to four fiscal modules: Exotic species can be important in many agroforestry systems. However, they cannot always be planted due to limitations imposed on properties according to the number of fiscal modules.
Cultural and training	Lack of rural internet infrastructure: For property owners, rural internet is still expensive and limited, which can hinder training for mixed planting silviculture.
	Lack of specialized technical assistance: Technicians in the field are essential to support the producer in mixed planting silviculture. Even in simple silviculture, there is a need to monitor the production system. Integrated pest and disease management is essential to ensure production. Given the lack of technical assistance for training, progress must be made to overcome this obstacle to train technicians in mixed planting silviculture.
	Lack of trained labor: There is a lack of qualified labor to implement mixed planting silviculture.

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TYPE OF BARRIER	DESCRIPTION
SATELLITE MONITORING	
Technical	Lack of investment in basic and applied research on high resolution imagery: Given the vast size of Brazil, it is not feasible to apply the same visual interpretation methodologies currently used in INPE's monitoring systems in new systems that use automatic methodologies. The automatic classification approach at the pixel level has performed well with medium resolution spatial images. However, high resolution images present new challenges. To overcome them, it is necessary to substantially increase investments in research related to automatic classification at the pixel level, object-based image analysis (OBIA) and other semantic approaches that allow for more complex automatic interpretations.
	Limited availability of high-resolution images: Brazil lacks a research agenda for high resolution image analysis. The launch of the CBERS-4A satellite in December of 2019 should help to overcome this barrier, but without investments to develop new generation monitoring systems, the country will not benefit from this technology in the long term.
	Lack of application of monitoring system data for territorial intelligence: Aside from the lack of available images and processing capacity, there are also barriers to gathering and interpreting this data. Good practice manuals on the creation and dissemination of spatial data indicate the need to systematically create and maintain metadata; that is, data that qualify the databases by providing information about the structure and meaning of the data. Unfortunately, a large part of the data publicly available on the Internet and generated by government agencies does not provide metadata, making using this data very difficult to use.
Economic and market	Lack of investment in national satellite technology and image processing methodologies: There are substantial economic barriers that affect all links of the satellite monitoring system value chain. Brazil suffered a great loss in the link related to the development and production of hardware with the accident that occurred in 2003 during the VLS-1 rocket tests, which resulted in the death of a large part of the technical team. After the accident, resources for the project were drastically reduced. The other planned projects also had budget cuts, with only a small portion of the budgeted resources being used. There is also a lack of government investment to apply data from monitoring systems to generate territorial intelligence, despite the isolated investments in the private sector in precision agriculture and scientific research on monitoring.
Cultural and training	Lack of knowledge of the technologies: There is a lack of knowledge, mainly among small and medium producers and municipal public authorities, on the existing monitoring systems and the role of territorial intelligence in the management of rural and municipal properties, states and the federation. This lack of knowledge is aggravated by a lack of training in the use of geotechnology. Although the situation has improved substantially in recent years (mainly in environmental agencies), small and medium rural landowners have limited knowledge of monitoring systems for land cover and land use change. This, together with the lack of territorial intelligence systems and incentives to disseminate the benefits of monitoring systems, means that landowners lack information with respect to the environmental compliance of their rural properties and how to best use their land.
	Lack of training to use the technologies: The lack of training in programming is another barrier to dissemination and training on the use of satellite monitoring systems. There is an increasing number of languages, software solutions and platforms for analyzing satellite images. However, to use these tools, there is a need for more training in programming for a wider range of professionals, such as agricultural and forestry engineers, among others.

Source: the author.

APPENDIX II - MEMBERS OF THE TECHNICAL ADVISORY COMMITTEE (TAC) AND SECTORAL CHAMBERS (SCS) INVOLVED IN THE VALIDATION STAGES OF THE TECHNOLOGY ACTION PLANS

NAME	INSTITUTION
Eduardo Speranza	Brazilian Agricultural Research Corporation
Domingos Valente	Federal University of Viçosa
Valderes de Sousa	Brazilian Agricultural Research Corporation
Alexandre Camargo Coutinho	Brazilian Agricultural Research Corporation
Bernardo Rudorff	Agrosatélite Ltda
Cláudio Almeida	National Institute for Space Research
Julio Minelli	Association of Biofuel Producers
Gilberto Menezes	Brazilian Agricultural Research Corporation
Carlos Gabriel Koury	Amazon Conservation and Sustainable Development Institute
Rodrigo Costa	National Institute for Space Research
Marcelo Baltazar	Companhia Siderúrgica Pecem
Camila Abelha	Fluminense Federal University
Ênio Pereira	National Institute for Space Research
Orestes Gonçalves Junior	F2Brasil S/A
Gustavo Nunes	Federal University of Rio de Janeiro
Marcia Carla Ribeiro de Oliveira	National Institute of Technology
Lucas Rosse Caldas	LRC Ambiental Ltda
Mauricio Henriques Jr.	National Institute of Technology
Marcelo Poppe	Management and Strategic Studies Center
Marcio Massakiti Kubo	Itaipu Binacional
Gilberto Fisch	National Institute for Space Research
Joaquim Augusto Pinto Rodrigues	National Institute of Technology
Fernando Martins	University of São Paulo
Edson Orikassa	Toyota Motors S/A
Patricia Boson	National Transport Confederation
André Gonçalves	National Institute for Space Research
Alberto Coralli	Federal University of Rio de Janeiro
Paulo Emilio Miranda	Federal University of Rio de Janeiro
Marco Aurélio Araújo	Ministry of Economy
Raphael Stein	National Bank for Economic and Social Development
Isabella Sousa	Ministry of Economy
Fernando Araldi	Ministry of Regional Development
Joana Borges Rosa	National Petroleum, Natural Gas and Biofuels Agency
Mário Henrique Mendes	Ministry of Environment

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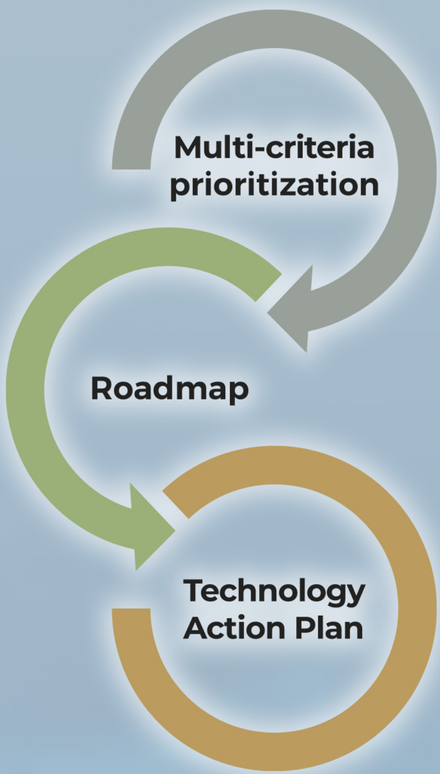
NAME	INSTITUTION
Katia Marzall	Ministry of Agriculture, Livestock and Supply
Sonia Regina Bittencourt	Ministry of Science, Technology and Innovations
Daniel Chang	Ministry of Science, Technology and Innovations
Antônio Marcos Mendonça	Ministry of Science, Technology and Innovations
Daniela Merlo	CAIXA
Eleneide Sotta	Ministry of Agriculture, Livestock and Supply
Morenno de Macedo	CAIXA
Euler Lage	National Petroleum, Natural Gas and Biofuels Agency
Gustavo Barbosa Mozzer	Brazilian Agricultural Research Corporation
Rafaella Aloise Freitas	National Confederation of Industry
Mariana Barroso	Energy Research Company
Luis Fernando Badanhan	Ministry of Mines and Energy
Márcio Rojas da Cruz	Ministry of Science, Technology and Innovations
Felipe Arias Fogliano de Souza Cunha	Financier of Studies and Projects
Rodrigo Rodrigues Fonseca	Financier of Studies and Projects
Marcus Vinicius Cantarino	National Confederation of Industry
Raquel Breda dos Santos	Ministry of Economy
Ronan Luiz Da Silva	Ministry of Economy
Maria José Amstalden Moraes Sampaio	Brazilian Agricultural Research Corporation
Rodrigo Vellardo Guimarães	Energy Research Company
Danielle Holanda	Ministry of Regional Development
Felipe Lenti	Amazon Environmental Research Institute
Barbara Bressan	Management and Strategic Studies Center
Gustavo Maranhão	Toyota Motors S/A
Raphael Guimarães Duarte	GreenAnt Ltda
Marcela Rezende	Brazilian Biogas Association
Markus Endler	Pontifícia Universidade Católica do Rio de Janeiro
Julio Cesar Chaves	Getúlio Vargas Foundation
Alexandre Camargo Coutinho	Brazilian Agricultural Research Corporation
Lucas Rios do Amaral	University of Campinas
Bruno Mariani	Symbiosis Investimentos Ltda
Yeda Maria Malheiros de Oliveira	Brazilian Agricultural Research Corporation
Giampaolo Queiroz Pellegrino	Brazilian Agricultural Research Corporation



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