A **BIG PUSH** FOR SUSTAINABILITY IN BRAZIL'S **ENERGY SECTOR**

INPUT AND EVIDENCE FOR POLICY COORDINATION

United Nations
ECLAC
cgee
Center for Strategic Studies and Management
Science, Technology and Innovation
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Empresa de Pesquisa Energética
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This document was prepared by Camila Gramkow of the Economic Commission for Latin America and the Caribbean (ECLAC) and Marcelo Poppe, Bárbara Bressan Rocha and Mayra Juruá Gomes de Oliveira of the Center for Strategic Studies and Management (CGEE), with contributions from experts of the Brazilian Energy Research Office (EPE).

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Foreword by the EPE

In the context of Energy Transition and responding to the challenges of climate change, countries have been building narratives that help to highlight different implications in terms of opportunities, risks and benefits, based on each country's domestic priorities and status. Within the multiple perspectives, one element stands out and emerges as a consensus: the key role of innovation in the search for sustainable solutions for increasingly complex and dynamic energy systems.

The Energy Big Push project presents itself as a valuable contribution in the context of a wide collective initiative involving several institutions and stakeholders. It aims to enhance governance and the quality of information on RD&I investment in the energy sector. In a world where technology is a key factor for any country to become part of the global economy, we understand that knowledge about the amounts invested and the quality of one's RD&I efforts, in addition to mapping the main players, can be determining factors for the success of a national sustainable development strategy.

In 2018, I represented Brazil at Mission Innovation, an international initiative aimed at creating an alliance to help raise investment levels in innovative clean energy solutions. From the perspective of a government official, I was able to see how difficult it can be to report on the volume of public or publicly-oriented investments that our country makes in energy RD&I. Although Brazil's investments were substantial, there was no integrated, comprehensive and structured database that brought together all the information required, and that could guide policy-making in this area, foster partnerships between the public and private sectors, and favour the global dissemination of Brazilian innovation and solutions, many of which are highly relevant for energy transition.

It was in our search for partners committed to that same objective that we found the CGEE and ECLAC. Our objectives were greatly in line with those set for ECLAC's Big Push for Sustainability. Building on that, we developed a new project in Brazil known as Energy Big Push, in partnership with the CGEE. This project provided resources, offered technical expertise and supported institutional coordination efforts to strengthen the initiative and foster local engagement, under our regional development policy. Therefore, it set the scene for productive efforts towards improving the governance of investment data on energy RD&I in Brazil. Along this trajectory, we were also able to count on important and enriching technical input from local, national and international institutions, such as the International Energy Agency.

Other Brazilian institutions also offered major contributions in terms of institutional engagement and coordination, such as the Energy Research Office (EPE), the Ministry of Foreign Affairs (MRE, or Itamaraty), the Ministry of Mines and Energy (MME), and the Ministry of Science, Technology and Innovations (MCTI), in addition to several others. Each one focused on their own areas of expertise, while maintaining open communication channels with the others. The resulting synergy turned the Energy Big Push into a successful project that promotes greater integration and understanding of RD&I investment levels, especially in clean or sustainable energies.

Among the many merits of this initiative, I would like to highlight two aspects in particular: its scope, and its process. The project did not limit its scope to attempting to build a database of public (and publicly-oriented) investments in energy RD&I (Axis 1). It also addressed other fundamental links for the development of innovation policies, focusing on indicators (Axis 2), policy instruments (Axis 3), and communication with stakeholders and decision makers (Axis 4). The results achieved so far provide useful insights for future developments and improvements, and for the challenge of internalizing them. They also provide important inputs for policy makers, in addition to increasing transparency and visibility on the importance of the links between innovation and energy transition. The second merit concerns the initiative's dynamic and collaborative process, which, through the involvement of several institutions with diverse interests, enabled the achievement of common goals. This is an important embryo for the type of integrated governance required for any project focused on energy innovation.

The Energy Big Push project, of which the EPE is a proud partner, is the beginning of a journey of the utmost relevance for Brazil. A journey that will turn our country into a key player in global energy transition.

Thiago Barral
President
Energy Research Office

Foreword by the IEA

The International Energy Agency (IEA) supports government efforts around the world to pursue key policy goals including energy access, affordability and sustainability. By tracking data, sharing best practice approaches and undertaking technical analysis across all fuels and technologies, IEA Family members including Brazil are well positioned to find real-world solutions to the pressing energy challenges of today and tomorrow.

The world needs more and better technologies to achieve energy and sustainability goals. This means that more innovation is needed today. The IEA *Tracking Clean Energy Progress* (TCEP) shows that most energy technologies are not on track to meet global energy and climate targets, and require further performance improvement and cost reduction. In fact, many of the energy technologies needed to reach long-term net-zero emissions either do not exist or are not ready at scale. Dedicated analysis on this topic will be featured in the IEA *Energy Technology Perspectives* (ETP-2020).

In addition, the unfolding COVID-19 crisis is putting unprecedented pressure on people, governments, and businesses around the globe. As nearly all economic activities, the energy sector has been severely affected. With smart and well-tailored policies, however, clean energy transitions can help kick-start economies. Governments are seeking near-term solutions to mitigate the negative impacts of the crisis, as well as medium-term levers to foster structural growth and future job creation. Energy innovation can play an important role here.

The Energy Big Push (EBP) project fits well within this context, and the IEA welcomed the opportunity to be a partner from the start. The EBP project aims to inform policy discussions about energy technology innovation in Brazil, with the view to accelerate clean energy transitions. After a year, the four working groups have delivered valuable insights to Brazilian decision makers and improved collective understanding of current trends. The IEA took an active role, including technical support and analyses, connection with experts from IEA Family countries and engagement with the international community during stakeholder events. The EBP project has contributed to strengthening the IEA's relationship with Brazil —a major regional and global actor in energy. All of this was made possible through the support and funding of the United Kingdom to the Clean Energy Transitions Programme (CETP).

Three successful aspects of the project are worth specifically mentioning: 1) effective collaboration; 2) high focus on data; and 3) forward-looking policy discussion.

First, and perhaps most importantly, the EBP has created a platform for key stakeholders in Brazil to connect, engage and collaborate. By bringing together relevant Ministries and institutions, common challenges may be explored collectively. Only through coordinated and targeted efforts can energy innovation deliver tangible outcomes for Brazil. Collaborative work such as the EBP are a great step forward, and the Center for Strategic Studies and Management (CGEE) and the Energy Research Office (EPE) deserve warm congratulations for their leadership. The role of international organizations in sharing experience was also welcomed —another opportunity for the IEA to work with the United Nations Economic Commission for Latin America and the Caribbean (ECLAC).

Second, the EBP has brought meaningful contributions to Brazilian efforts to collect and track innovation data, such as public spending in energy research and development. Access to more and better data is key to inform policy making, and to ensure that innovation activities in Brazil are aligned with the country's long-term national priorities. It will be critical to confirm this progress over time and further enhance this work going forward, with systematic data tracking put in place in subsequent years.

Finally, the EBP has provided project partners, and notably decision makers within the Ministry of Mines and Energy (MME) and the Ministry of Science, Technology and Innovations (MCTI), with a broad overview of Brazil's energy innovation landscape and forward-looking policy considerations. While many aspects warrant further examination, this is a necessary first step for policy makers to identify strengths as well as areas for possible improvement. Stakeholders now share a common understanding of current trends and pressing challenges, and are therefore in a better position to explore policy options together.

For these reasons, among others, I would like to express once more the IEA's support to the Energy Big Push project —and send my warm congratulations to the hard-working teams that helped put it together.

Dave Turk
Acting Deputy Executive Director and
Head of the Strategic Initiatives Office
International Energy Agency

Preface by the CGEE

The Center for Strategic Studies and Management (CGEE) was created with the mission of supporting high-level decision-making in topics related to science, technology, innovation and education, through prospective studies and strategic assessment conducted in broad cooperation with experts and institutions of the National Science, Technology & Innovation System (NSTIS). Along these lines, studies on sustainable development in various sectors of the economy —of both national and global interest— are developed through the Positive Agenda for Climate Change and Sustainable Development project. Under this project, the energy sector is particularly relevant, given its cross-cutting nature and its impacts on people's development and well-being.

Past industrial revolutions facilitated a worldwide leap in economic growth and social development, always associated with an increase in the supply of energy produced from different sources, in particular fossil fuels such as coal, oil and gas. As we all know, this brought along a surge in the environmental impacts caused by the release of carbon dioxide and methane into the atmosphere. In response to this threat, governments around the world have committed to finding solutions for a sustainable and low-carbon development pathway. This is the case of the Paris Climate Agreement and the United Nations 2030 Agenda, both developed with significant participation from Brazil, and of which the country is a signatory.

We are experiencing a new industrial revolution, fundamentally based on the digitization and automation of industrial processes, the increase in the supply of energy from alternative sources, and the bioeconomy. Energy transition is inevitable and essential to set nations on a low-carbon, resilient, dynamic and prosperous economic trajectory, with measurable improvements in the quality of life for the entire population. Any actions that can accelerate this process are more than welcome. It is in this context that, under national, regional and global initiatives, the Energy Big Push project offers a collaborative environment to promote a constructive dialogue among different players in the energy sector, fostering policies, programmes and projects that are capable of accelerating energy transition in Brazil.

Thus, the Energy Big Push project aims to monitor and assess innovation efforts in the Brazilian energy sector and drive their implementation, with a focus on expanding the technical and institutional capabilities of the national innovation system, particularly around issues related to energy production, transmission and end use. Engaging national, regional and international partners in the Energy Big Push project is of critical importance, as well as building on their competences and adding legitimacy for the implementation of action plans, while serving as an international benchmark for the important innovation efforts in Brazil's energy sector.

There are certainly methodological and analytical improvements to be made in future stages, such as expanding data collection and analysis on R&D projects, improving innovation indicators and perfecting incentive mechanisms for investment in energy technologies in Brazil. However, the project already offers a unique panorama of innovation in the country according to international metrics, providing a volume of data and information that will enable decision makers to improve the coordination of strategic policies and programmes with a view to promoting and financing technological innovation in the field of energy in Brazil.

Marcio de Miranda Santos
President of the CGEE
Center for Strategic Studies and Management

Preface by ECLAC

The United Nations Economic Commission for Latin America and the Caribbean (ECLAC) has recently completed seven decades of existence, during which it has been studying and proposing policies for the development of the region. ECLAC established its first formal representation in Brazil in 1960. Since then, it has engaged in discussions, research and technical cooperation for the development, monitoring and evaluation of programmes and actions aimed at economic, social and environmental development. The ECLAC Office in Brazil works in cooperation with several federal government agencies in carrying out analyses, providing technical assistance and training, organizing events and fostering strategic dialogues to promote the exchange of experiences and learning among its Latin American and Caribbean peers, in addition to supporting states and municipalities, professional associations, universities and civil society.

Over the past few years, we have been striving to structure a renewed approach centred around a Big Push for Sustainability, with the goal of supporting countries in the region in building more sustainable development styles. The Big Push for Sustainability is an approach based on coordinating policies in order to mobilize and accelerate sustainable investments. These investments are able to produce a virtuous circle of economic growth, income and job creation, and reduction of inequalities and structural gaps, while maintaining and regenerating the base of natural resources on which development depends.

We have been working on this approach at an auspicious moment, in which Brazil and the world share a common concern with the recovery of economic activity on a sustainable basis. As the Secretary-General of the United Nations, António Guterres, says, if we make the right choices, the COVID-19 pandemic can mark the rebirth of society as we know it today, creating a world in which we protect present and future generations on the basis of the 2030 Agenda and its 17 Sustainable Development Goals. As a practical approach towards translating this vision into action in the region, the Big Push for Sustainability will not leave anyone behind, and should enable us to build societies that are more egalitarian and inclusive, and also more resilient in the face of threats from pandemics, climate change and many other challenges that we face.

Investments towards the construction of sustainable energy systems represent one of the great opportunities for the Big Push for Sustainability in Latin America and the Caribbean. ECLAC has developed a definition for energy transition at regional level, according to which it can be understood as the process of change in policies, institutions, regulations and investments that promote the generation and more sustainable uses of energy aiming at decarbonizing the economy. Its priorities are: higher generation of electricity from renewable sources, with an emphasis on variable renewable energies; greater energy efficiency of energy systems, including transport; more sustainable management of fossil fuels and biofuels; and greater energy complementarity, leading to less regional energy vulnerability.

We have had the pleasure of counting on Brazil's engagement in regional cooperation forums in the area of energy, including the Regional Energy Planners Forum, and the Regional Observatory on Sustainable Energy (ROSE, which aims to design, implement and monitor sustainable energy strategies, plans and policies based on objective evidence). In addition, Brazil has also engaged in the Regional Political Dialogues on Energy Efficiency, led by ECLAC in collaboration with other entities with which we have worked at the regional level, such as the Latin American Energy Organization (OLADE), the Inter-American Development Bank (IDB) and the United Nations International Renewable Energy Agency (IRENA).

The Energy Big Push project, which aims to accelerate investments in technological and innovative capabilities for a sustainable energy transition in Brazil, has brought ECLAC and Brazil even closer together. The project, launched in 2019, resulted from a partnership between ECLAC and the Center for Strategic Studies and Management (CGEE), building on initial efforts undertaken by Brazil's Energy Research Office (EPE). This fruitful cooperation took place within the framework of ECLAC's technical cooperation programme with the German International Cooperation Agency, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

ECLAC would like to thank the EPE and the CGEE for their prolific work and for the trust placed in this cooperation. We also thank the Brazilian Ministries of Foreign Affairs, Mines and Energy, and Science, Technology and Innovations, as well as other national agencies involved in the project. We are also grateful to the International Energy Agency for their engagement and technical input, which have been of great importance for the Energy Big Push in Brazil. ECLAC remains available and committed to continuing to deepen our work in collaboration and partnership with Brazil.

We are therefore very pleased to present this publication, entitled *A Big Push for Sustainability in Brazil's energy sector*, which provides an overview of investments in energy innovation in Brazil, a performance analysis of several low-carbon energy solutions and guidelines for incentive mechanisms to accelerate clean energy innovation in Brazil.

Without further ado, we cordially invite our readers to dive into these pages in order to broaden their understanding of the current energy innovation environment in Brazil; the challenges and opportunities for clean energy innovation; the lessons learned from international experience; and possible ways to build technological capacity in sustainable energies. This work is in line with our efforts towards a Big Push for Sustainability in Brazil in the light of our current social, economic and environmental concerns, which clearly demand a new style of development with increased equality and sustainability.

Carlos Mussi
Director of ECLAC Office in Brazil
Economic Commission for Latin America and the Caribbean

Introduction

Background and rationale

The climate and sustainability commitments of the Paris Agreement and the 2030 Agenda and its 17 Sustainable Development Goals have inspired several global, regional and national initiatives. In this sense, the Energy Big Push (EBP) Brazil project originated from the convergence of motivations and synergic efforts in the activities of its partners that permeate the themes of sustainable development, energy transition and international cooperation.

In 2015, a global initiative led by 24 countries and the European Union was launched aimed at accelerating clean energy innovation, named Mission Innovation (MI). The representatives of the Brazilian government in the MI —the Ministry of Foreign Affairs (MRE, in its Portuguese acronym) and the Ministry of Mines and Energy (MME, in its Portuguese acronym)— mobilized the Energy Research Office (EPE, in its Portuguese acronym) in order to conduct a survey on investments in research, development and demonstration (RD&D) in energy technologies to support the monitoring of innovation efforts in the energy sector in the country.

The EPE took the first steps in this direction and organized a first database of public and publicly-oriented investments in RD&D between 2018 and 2019, using the classification of the International Energy Agency (IEA). Based on this initiative, the need to incorporate other data sources and expand the time series was identified to improve the understanding of the main efforts towards energy innovation in the country through a single structured and harmonized data set. In this context, the Center for Strategic Studies and Management (CGEE, in its Portuguese acronym) was invited, as a strategic partner, to design and implement a collaborative project that would be able to build technical and institutional capacity to meet the need to expand access to strategic data for decision-making in the energy sector.

The Brazilian government's need for strategic information and input to accelerate a sustainable and low-carbon energy transition fully coincides with the Big Push for Sustainability approach in the energy sector. The United Nations Economic Commission for Latin America and the Caribbean (ECLAC) has been developing this approach since 2016 to support countries in the region in building more sustainable development styles. The Big Push for Sustainability represents a coordination of policies (public and private, national and subnational, sectoral, fiscal, regulatory, financial, planning, etc.) that leverage national and foreign investments to produce a virtuous cycle of economic growth, generation of jobs and income, reduction of inequalities and structural gaps, and promotion of environmental sustainability.

Investments in the expansion, integration and diversification of clean and renewable energies represent one of the major opportunities for a Big Push for Sustainability in Latin America and the Caribbean, due to its multiple positive impacts in several areas, which are discussed in more detail in Chapter I. In the context of ECLAC's technical cooperation programme with the German technical cooperation agency Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) to support selected countries in the region in a position to develop their strategies for implementing the 2030 Agenda, in line with the Big Push for Sustainability approach, ECLAC joined the efforts of CGEE and partners of the Brazilian government to promote a big push for investments with a focus on clean energy innovation in Brazil.

The IEA also joined efforts for an Energy Big Push in Brazil, within the scope of its Clean Energy Transitions Programme (CETP). This programme's mission is to accelerate global clean energy transitions, mainly in major emerging economies, through activities that include collaborative analytical work, technical cooperation, training and capacity building and strategic dialogues. The programme provides independent cutting-edge support to governments whose energy policies will significantly influence the prospects for —and the speed of— the global transition towards more sustainable energy production and use, with Brazil being one of the programme's priority countries. The IEA's extensive experience in the energy field, including in collecting, analysing and monitoring global energy research, development and demonstration expenditures, as well as technical expertise across all fuels and energy technologies, clearly converges with EBP.

In 2019, based on the synergistic motivations of the partners, the EBP project kicked-off within a framework of multi-institutional collaboration at the international, regional and national levels, creating a unique environment to exchange of experiences and share knowledge for an Energy Big Push in Brazil.

The Energy Big Push Project

The objective of the Energy Big Push (EBP) project is to support the promotion of more and better public and private investment in sustainable energies with an emphasis on innovation, contributing to an Energy Big Push in Brazil.

The project is structured around four areas of activity —or axes. Each axis corresponds to a specific objective, as described below:

- Axis 1 – Development of a process for collecting, structuring and managing data on public and private investments in energy research, development and demonstration (RD&D);
- Axis 2 – Survey of technical, economic, social and environmental performance indicators associated with low-carbon energy solutions;
- Axis 3 – Identification of strategic guidelines and key policy instruments to accelerate investments in energy innovation; and
- Axis 4 – Innovative and effective communication strategy of project results, targeted at decision makers.

For each of these axes, working groups were formed, which met regularly and offered technical and data contributions to the EBP project. In addition to the CGEE, the EPE, ECLAC and the IEA, the working groups were formed by experts from MRE, MME, the Ministry of Science, Technology and Innovations (MCTI), the Brazilian Electricity Regulatory Agency (ANEEL), the National Agency for Petroleum, Natural Gas and Biofuels (ANP), the Funding Authority for Studies and Projects (FINEP), the National Council for Scientific and Technological Development (CNPq); the Brazilian Industrial Innovation Agency (EMBRAPII), and the Institute for Applied Economic Research (IPEA) —see participants list in the annex. Therefore, more than a dozen national, regional and global institutions have been mobilized and actively engaged with the EBP, bringing the universe of energy and the universe of innovation stakeholders closer. The collaboration of each partner takes place on a voluntary basis, in an effort to value the different experiences of each participant, in an effort to value the collective intelligence of the group, and add value to the results obtained under the project.

The inputs and interactions of the working groups informed the preliminary technical reports on Axes 1, 2 and 3, with initial estimates and considerations for each of them. The preliminary reports were presented and discussed during the Energy Big Push Workshop, held at the CGEE in October 2019. The workshop aimed to provide exchange of experiences, learning among peers and an opportunity to review and improve the preliminary results of the project. The event was attended by 47 people, including experts and representatives of the project's partner institutions (see list of participants in table A1). The enriching discussions of this workshop generated key inputs for the final reports on Axes 1, 2 and 3, and for the communication and engagement activities under Axis 4.

The reports produced within the framework of the EBP are, therefore, the result of a collective effort and the contributions of several partner institutions and experts that are working on the theme. These are:

- The Axis 1 final report: Overview of energy innovation investments in Brazil: Data for an energy big push
- The Axis 2 final report: Performance indicators associated with low carbon energy technologies in Brazil: Evidence for an energy big push
- The Axis 3 final report: Incentive mechanisms for clean energy innovation in Brazil: Paths for an energy big push
- The EBP final project report, which is the present document, named "A Big Push for Sustainability in Brazil's energy sector: Input and evidence for policy coordination", presents a synthesis and integrates the results of each axis in the light of the Big Push for Sustainability approach.

The EBP is expected to consolidate itself as a process of co-creation of several studies and analyses to support decision-making; capacity building and learning acquired by the teams of the various agencies involved on the project on issues related to sustainable energy, innovation and investments; and, finally, the development of recommendations on the topics covered by the project, which may serve as inputs for public policies to accelerate investments in clean energy in Brazil, with a focus on innovation.

I. Big Push for Sustainability

The present days are marked by an attempt to restore the dynamism of economic activity and people's quality of life, both in Brazil and in the whole world. The paths towards this recovery have been increasingly discussed. One reason for this is that, in addition to cyclical aspects, structural challenges can make economies more susceptible to crises and less resilient to their impacts. Such structural aspects, including global limitations, climate emergencies and inequality-driven inefficiencies, determine the long-term sustainability of development. The world today requires a new development style, with equality and sustainability at its core. This is the Big Push for Sustainability —a vision developed by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) to guide its new approach to supporting countries in the region in the construction of more sustainable development styles. The 2030 Agenda and its 17 Sustainable Development Goals (UN, 2015) guide and promote ECLAC's vision.

The Big Push for Sustainability approach is a set of coordinated policies (public and private, national and subnational, sectoral, fiscal, regulatory, financial, planning, etc.) that may leverage national and foreign investment to produce a virtuous circle of economic growth; income and job creation; reduction of inequalities and structural gaps; and promotion of environmental sustainability (ECLAC/FES, 2019). In this approach, the massive investments required for the transition towards a healthy, resilient, low-carbon, inclusive and sustainable economic model are presented as an opportunity to generate a big push for a new cycle of economic growth and the promotion of equality, contributing to the construction of a more sustainable development style underpinned by an economic, social and environmental tripod. The Big Push for Sustainability can be the guiding principle for economic recovery, reduction of vulnerabilities and development of resilience with sustainability.

A. There is a pressing need to change the development style

The starting point for the Big Push for Sustainability is the urgency of changing development styles. It has not been possible to eliminate structural gaps linked to development in Latin American economies, including bringing down competitive and technological asymmetries, converging with higher income levels, or reducing social inequality once and for all.

As a region, Latin America's economic growth rates have been unable to restore jobs and eradicate poverty, a situation that is aggravated by the crisis resulting from the recent COVID-19 pandemic, which has contributed to keeping the region as one of the most unequal in the world. Inequality is a source of significant inefficiencies in the economy, as it deteriorates the institutional environment, policies and efforts, weakening innovation and capacity-building efforts that are a requisite for development (ECLAC, 2018). For example, inequality limits the dissemination of education and skills through society, creating barriers to innovation, creativity, and other efforts, as a result of different types of discrimination. It also inhibits a country's ability to overcome a privilege-based culture, which hampers the rise of new actors, sectors and ideas (ibid.). In addition, persistent inequalities inhibit the creation of a larger-scale domestic market, preventing the development of entire economic chains that require a minimum scale to make their operation viable and, therefore, also preventing the achievement of better-paid jobs, higher productivity levels and improved working conditions. On top of that, there is a sustainability crisis, which can be understood as production and consumption patterns that are incompatible with the biosphere's ability to continue offering minimum biophysical conditions to maintain human well-being for present and future generations (ECLAC/FES, 2019). This sustainability crisis reinforces and deepens the structural gaps that characterize the socioeconomic development of several countries in the region.

In Brazil, climate change is projected to significantly impact the country's economy, with the agricultural sector being the most vulnerable of all. Relevant crops for subsistence farming, such as cassava, maize and beans (PBMC, 2013; IPCC, 2018) will be affected, aggravating poverty and food insecurity, particularly in the Northeast and North of the country. In other words, global warming may increase the already significant social vulnerabilities and regional disparities. Key export crops will also be impacted, such as soy, coffee and cotton (ibid.), which will subject the exporting sector to increasing vulnerabilities. Thus, global warming tends to deepen structural gaps in development, notably inequality and external vulnerability. The climate emergency illustrates how structural aspects can weaken economic performance and compromise social development.

Failure to address the sustainability crisis today implies having to tackle much more acute structural issues tomorrow, including poverty, migration, food insecurity, loss of productivity and competitiveness, and external vulnerability. Reflecting on the sustainability crisis back in the 1980s. Raúl Prebisch, a great Latin American economist, said, "We are not facing new problems, but old problems that have become more serious" (Prebisch, 1980). The widening of structural gaps makes economies much more exposed and vulnerable —and less resilient— to future shocks and crises, including the imminent impacts of a climate emergency.

Global warming and the increasing deterioration of natural resources highlight the fact that it will not be possible to simply replicate the policies adopted by developed economies in the past, as such approach would exacerbate the sustainability crisis. In addition, worldwide tectonic shifts also require new responses and changes in development styles. The new technological revolution (biotechnology and nanotechnology, the digital economy, etc.), demographic transition, and new geopolitics (which emerged with the rise of China) tend to radically transform life in society (ECLAC, 2016 and 2018). Furthermore, the impacts of the recent COVID-19 pandemic add to these tectonic shifts. The extent of this crisis is still unknown, as it is an unprecedented situation in recent history. These changes reinforce the need for action.

In order to counter the unsustainability of current development styles and address ongoing tectonic shifts, a new generation of sustainable development policies is required. On the one hand, this sustainability crisis imposes new contours, set by the limits of the biosphere in which development may occur; on the other, it provides new economic growth engines with higher levels of equality, including resilient and low-carbon investments (Gramkow, 2019; ECLAC/FES, 2019). For example, the estimated investment required to make the Brazilian economy more resilient, and with lower carbon emissions, is substantial —ranging from R$ 890 billion (IDB, 2017) to US$ 1.3 trillion (IFC, 2016) by 2030. However, it may drive a new cycle of economic growth with greater equality in the country. The transition to a sustainable, healthy, resilient and low-carbon production and consumption matrix can leverage structural changes in development styles. By merging structural issues in Latin American development with sustainability concerns, the Big Push for Sustainability highlights the growing importance and the inseparability of these themes (Gramkow, 2019).

B. The Big Push for Sustainability as a tool for building sustainable development styles

The Big Push for Sustainability emerged as a driving idea, even before it turned into a concept of greater theoretical density. Its main conceptual aspects were developed by ECLAC in recent works (ECLAC, 2016 and 2018). It can be said that the Big Push for Sustainability is an evidence-based analytical approach to guide and support the construction of more sustainable development styles. The key element of this approach is investment, as it is the main link between the short and the long term.

Today's investments account for tomorrow's production structure, which in turn determines competitiveness, productivity, and engagement in international trade. In addition, it also determines a country's capacity to generate quality jobs with productive inclusion, and whether the economic activity will be polluting or ecological. It is now truer than ever that economies that invest little tend to position themselves on the periphery of the global economic system. Investment is a fundamental aspect of the profound and structural changes that are already underway, from technological revolutions (digital transformation of the economy, bioeconomy, nanotechnology, etc.) to demographic transition. Only through investment may these changes become an opportunity for sustainable development, rather than new challenges for the survival of the region's economies and sociopolitical systems. In short, the development style that will prevail in the future depends crucially on the type of investment that is made today.

The Big Push for Sustainability is inspired by P. Rosenstein-Rodan's idea that a substantial set of complementary investments is required —a big push— to enable a definitive leap in development. ECLAC has revisited and updated this notion taking into account the specificities of Latin American development, and the sustainability of its three pillars (economic, social and environmental).

> "There is a minimum level of resources that must be devoted to a development programme, if it is to have any chance of success. Launching a country into self-sustaining growth is a little like getting an aeroplane off the ground. There is a critical ground speed which must be passed before the craft can become airborne. ... Proceeding 'bit by bit' will not add up in its effects to the sum total of the single bits. A minimum quantum of investment is a necessary, though not sufficient, condition for success. This, in a nutshell, is the contention of the theory of the 'big push theory'."
>
> Rosenstein-Rodan (1957)

This analogy between the process of changing a development style and an aeroplane taking off has two central points: minimum scale and investment coordination. Just as an aeroplane may only leave the ground if it reaches a minimum speed, a development style can only be changed if a significant amount of investment is mobilized. In addition to a minimum scale, the analogy with bits, which are only individually viable if they are engaged simultaneously, emphasizes that every investment should be coordinated with parallel investments in other sectors so that each one is profitable and viable. For example, investing in renewable electric energy sources, such as distributed photovoltaic generation, will only be profitable if simultaneous investment is made in smart electricity grids, and vice versa. Not only does this point illustrate the importance of a significant mobilization of funds, but also of their combination, so that a more sustainable development style can be made viable.

Complementarity also applies to investments in the construction of scientific, technological and innovative skills and competences, which may enable not only to devise technical solutions for sustainability, but also to create more sustainable sources of competitiveness, based on innovation and value-adding (Fajnzylber, 1988; ECLAC, 2016). Pursuing environmental sustainability requires advancing the same elements that are needed to achieve socioeconomic sustainability: production diversification, and an increase in the relative weight of sectors with greater technological intensity in the economy. Therefore, it is essential to invest in a strong national innovation system, adapted to the new needs of the transition to a new development style. Green innovation (or "eco-innovation") is a driver of sustainable development, as it acts on two externalities: the negative environmental externality, by reducing the footprint on the environment; and the positive innovation externality, which generates feedback, spillovers and positive interactions in the economic fabric. Green innovation can be based on both modern, flexible and smart technologies, such as unconventional renewable energy sources (wind, solar, etc.); advanced fuels (e.g. second generation ethanol); bioeconomy or circular economy technologies (efficiency in the use of inputs, recycling, etc.); as well as traditional and social technologies, such as sustainable practices developed by cooperatives, associations and traditional, rural and local peoples and communities.

Under the Big Push for Sustainability approach, complementary and scale investments should be guided by the development style that one aims to achieve. Firstly, the pillars of such new development style should be understood. There is no single sustainable development style available, but a wide range of possible options. Therefore, it is necessary to understand and capture what each society envisions and desires in terms of its future development. There may be societies that aim for an industrial-export economy of high-tech manufactured goods, while others may prefer to pursue a more service-based economy, for example.

Many countries have their own set processes that shed light on these pillars, including planning strategies, sectoral plans, public spending priorities and policy guidelines. National aspirations are by far the most important pillar of the new development style to be built. However, other elements can also help to inform this process. For example, each country's vocations are also an important aspect to consider, including the type and availability of natural resources, the abundance and qualification of human capital, and existing technological and productive skills. In addition, international coordination mechanisms and the internalization of the international community's responses to global challenges should also be taken into account, including those expressed in the 2030 Agenda and its 17 Sustainable Development Goals (UN, 2015); in the Paris Agreement; in the New Urban Agenda (Habitat III); and in several other international agreements that result from consensus-building processes.

In order for investments to be compatible with the construction of sustainable development styles, the Big Push for Sustainability approach also requires them to be guided by another pillar: that of the triple efficiency. The first of these efficiencies is known as Schumpeterian efficiency, according to which a more integrated, complex and knowledge-intensive production matrix generates positive learning and innovation externalities, which permeate the whole value chain. Production structures that facilitate an accelerated flow of information and knowledge tend to translate into economies that are more efficient, more innovative and better prepared to perform competitively in markets that better remunerate the goods and services produced. This efficiency is strongly associated with the supply side, i.e. the installed productive and technological capabilities (and those to be developed).

The second efficiency —Keynesian— highlights the fact that there are efficiency gains from specializing in goods whose demand grows relatively more, generating multiplier effects and positive impacts on the economy and jobs. Economies that are able to access expanding markets can increase their production at a faster rate than they increase their costs (economies of scale) and, when operating different businesses simultaneously, can increase their joint production efficiency, with consequent cost-reduction and quality-improvement (scope savings). This second efficiency highlights elements on the demand side, which are reinforced, creating a virtuous circle of competitiveness, innovation and productivity.

Keynesian efficiency is closely related to Schumpeterian efficiency, since the fastest growing markets tend to be those with the greatest technological and innovation dynamism, that is, the income elasticity of demand is greater for more technologically complex goods. In other words, as income increases, the demand for simpler goods (for example, cassava or bananas) grows less than the demand for more elaborate goods (e.g. smartphones or notebooks). The implication, in international terms, is that countries that specialize in less elaborate goods and services (for example, commodities) tend to remain on the periphery of global economic growth, as the demand for their products grows less than the demand of countries that specialize in more technologically advanced products. This point illustrates the critical importance of investing in innovation.

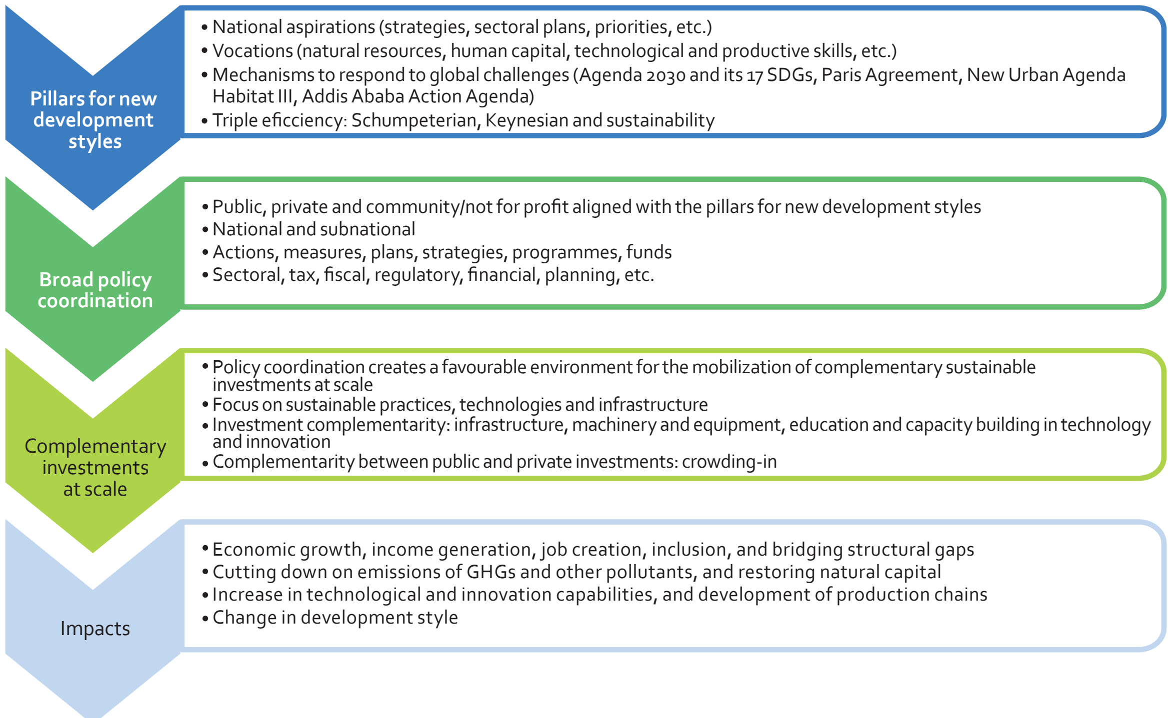
Together, Schumpeterian and Keynesian efficiencies create the conditions for favourable competitive performance. However, a third efficiency is required to guarantee the long-term sustainability of a development style. Known as the sustainability efficiency, it is linked to the classic economic, social and environmental tripod. This efficiency points out that investments ought to be economically viable, which requires considering the sources of funding and resources. From a social perspective, and also taking into account social justice and the promotion of equality, the Big Push for Sustainability requires a safe and fair dispute-resolution system, which does not exclude anyone. The environmental axis of this sustainability efficiency reinforces the fact that sustainable investments should reduce the environmental footprint and environmental impacts, while restoring the natural capital's production capacity (for example, by restoring degraded pastures). Together, Schumpeterian, Keynesian and sustainability efficiencies form the triple efficiency, which is another investment guiding pillar required to build sustainable development styles.

Under the Big Push for Sustainability approach, developing and coordinating policies around the pillars of a development style is the key to unlock domestic and foreign investment, not only in sustainable practices, technologies, value chains and infrastructure, but also in scientific, technological and innovative capabilities, as well as the education required to provide the workforce with the skills they will need in the future. Coordination is both the critical challenge and the main opportunity for the Big Push for Sustainability. If a wide range of policies (public and corporate, national and subnational, sectoral, tax, regulatory, fiscal, financial, planning, etc.) are aligned and cohesive with the pillars of a new development style, a favourable environment to mobilize the necessary investment will be established, and this environment will be anchored in reduced uncertainties, corrected price signals and an appropriate policy mix. The consequent increase in sustainable investments will then lead to a virtuous circle of economic growth, job creation, development of production chains, and reduced environmental footprint and environmental impacts, while restoring the productive capacity of natural capital (see diagram I.1).

Therefore, the Big Push for Sustainability can be defined as the development and coordination of policies to mobilize a set of complementary and scale investments that may drive a virtuous circle of economic growth, job creation, development of production chains, and reduction of environmental footprint and environmental impacts, while restoring the productive capacity of natural capital, all together and at the same time. This is what ECLAC proposes for a new development style for the region, with sustainability and equality at its core.

ECLAC launched a discussion on opportunities and challenges related to a Big Push for Sustainability in Brazil, following a seminar held in partnership with the Center for Strategic Studies and Management (CGEE) in 2018 (ECLAC/FES, 2019). One of those opportunities stands out: Brazil's great potential for low-carbon investments, in the order of US$ 1.3 trillion by 2030 in sectors such as renewable energy, urban infrastructure (mobility, buildings, waste, etc.) and industry (IFC, 2016). Other highlights included the competitive gains of firms in Brazil that already invest in sustainable technologies (in terms of cost reduction, quality increase, market share, access to new markets, etc.); easier access to funding for businesses that have environmental and social governance mechanisms in place; and the existence of a broad base of productive and technological capacities focused on sustainability. Another point identified during the seminar was the opportune moment we are living now, during which Brazil's economic recovery is under discussion. This context can offer the country an opportunity to direct efforts towards accelerating sustainable investments.

Diagram I.1
The Big Push for Sustainability Approach



Source: Created by the authors based on Economic Commission for Latin America and the Caribbean (ECLAC)/Friedrich Ebert Stiftung (FES), "Big Push Ambiental: Investimentos coordenados para um estilo de desenvolvimento sustentável", *Perspectivas*, Nº 20, (LC/BRS/TS.2019/1 and LC/TS.2019/14), São Paulo, 2019.

Coordination is fundamental in this discussion, as a great potential has already been identified to unlock sustainable investments in the country through a robust and detailed policy coordination effort, which may remove contradictory signs and barriers. However, Brazil also faces many challenges, including the costs related to carbon lock-in (associated with the technological paradigm transition, especially in the most polluting sectors); the reduced fiscal space for designing new policies, particularly in the context of Constitutional Amendment 95/2016; and the country's federal structure, which imposes the need for broad coordination among federative entities. Building on this more general discussion, ECLAC has launched technical cooperation efforts on specific topics to try to land the Big Push for Sustainability approach on concrete applications, among which the Energy Big Push Brazil project stands out.

C. A Big Push for sustainable energy sources in Brazil

From the perspective of the Big Push for Sustainability, the discussion on pathways towards environmental sustainability and equality is a discussion on development, since the Big Push for Sustainability consists of identifying synergies between sustainable investments and economic development with equality. Although trade-off analyses are important, there are significant and important complementarities that can leverage changes in development styles. From this perspective, the Big Push for Sustainability can be seen as an approach that deeply explores synergies that lead to a greater systemic efficiency in the development style. By fostering greater labour productivity and rationality in the use of natural resources and in the emission of pollutants, as well higher efficiency in the use of fiscal resources, this approach can help to reduce structural gaps in development through effective public policies. Along this line, ECLAC has sought to identify key sectors for investment, i.e. map those sectors, technologies and value chains that can offer a major contribution to a Big Push for Sustainability in terms of the co-benefits generated.

Clean energy represents one of the great opportunities for a Big Push for Sustainability in the Latin America and Caribbean region, due to its multiple positive impacts in several areas. Increasing energy supply to meet the region's future energy needs from diversified renewable sources and energy efficiency is a clear way to build more economically, socially and environmentally sustainable development styles. From an economic perspective, investment in this area induces economic growth and job creation through the multiplier effect of investments in the value chain. Given that Brazil already has productive and technological capabilities installed for renewable energies (hydroelectricity, biofuels, wind power, battery sector, etc.), this is a typical case of the type of economic benefit in question, as the gains along the chain can be retained in the country itself (instead of going overseas, as is the case with many countries that lack domestic industrial capabilities). Especially in the ethanol and wind industry chains, the country not only has accumulated competences in the productive sector and in the science, technology & innovation (ST&I) sector, but also accumulated knowledge and learning about the development and coordination of the necessary policies to build internal renewable energy capabilities.[1]

In addition, investments in renewable energy and energy efficiency reduce dependence on fossil fuels, which are imported in most countries in the region. Brazil, despite being an oil producer and exporter, is a net importer of fossil fuels such as coking/steam coal, coke, petroleum products (notably diesel and gasoline) and natural gas (EPE, 2019). Fossil sources are often international commodities subject to high price volatility (including external price peaks and troughs) and supply interruptions due, among other factors, to political instability in the main producing countries (IEA, 2014). Thus, investing in renewable energy sources reduces external dependence on fossil energy sources, while contributing to national energy security and sovereignty and to reducing external vulnerability.[2]

The energy sector is key to development. The coverage, cost, reliability and security on which people and organizations (including firms and governments) may rely to have access to energy are central aspects of a country's sovereignty and systemic competitiveness. For a long time, ECLAC has pointed out that competition in the international market does not take place among companies alone. It actually involves productive systems, educational, scientific and technological structures, and energy, transport and telecommunications infrastructures, among others (Fajnzylber, 1988). It is in this regard that competitiveness occurs as a result of a systemic process, in which people's and organizations' access to energy plays a central role, especially in large countries such as Brazil. The energy infrastructure determines the degree of energy integration of a given region, and each place's ability to access the vast co-benefits offered by energy. These include those opportunities for production development that only become available when there is wide and secure energy supply, particularly for industrial sectors. Investing in renewable energy contributes to higher levels of efficiency, resilience and integration in the energy system, which in turn reduces the systemic costs for the country's economy, leading to greater productivity and competitiveness in various sectors.

From a social perspective, investing in renewable energies is a path towards universal access to electricity. As modern sources of renewable energy (such as photovoltaic panels and wind power) are modular, their generation scale can be adjusted according to demand, and do not necessarily have to be connected to the transmission grid. This enables them to be installed in remote regions, especially those isolated from the National Interconnected System. It is not by chance that reliable, sustainable, modern and affordable access to energy for all is an explicit Sustainable Development Goal (UN, 2015). This access also helps to improve public security (by enabling public lighting, for example); expand access

[1] See Rennkamp, Westin and Grottera (2020), for example, for the case study of the rapid expansion of wind power and the development of its production chain in Brazil, which illustrates how the coordination of supply policies (e.g. funding combined with local content policies) and demand (e.g. auctions), among others, mobilized large investments in wind generation (more than US$ 8.2 million in 2014), capacity building, expansion of the national industry, and national technological and productive skills (today, 131 Brazilian manufacturers produce 77 items in the wind power chain).

[2] See Gramkow, Brandão and Kreimerman (2019) for a case study of a country in the region that has achieved impacts of this nature. Uruguay has implemented several measures under its Energy Policy 2005-2030, which led, in less than a decade, to a structural change in its energy mix. The country's share of renewable energy sources doubled, reaching 60% in 2017; emissions dropped (in 2017, Uruguay reached its lowest absolute level of carbon dioxide emissions since 2007); and significant foreign investments were made in the country (US$ 1.4 billion in 2015). In addition, Uruguay achieved universal access to electricity, while reducing energy imports (i.e. the share of imported primary energy supply dropped from 52.5% in 2007 to 15.1% in 2017).

to health services (e.g. operating equipment or tests that require electric power) and education (e.g. by allowing people to study at night or to access distance-learning); reinforce food security (by allowing food to be refrigerated, for example); and access goods and services that enable broader socioeconomic inclusion, production diversification and added value. In other words, investment in renewable energies can substantially contribute to a more egalitarian development style, and access to energy can translate into access to opportunities and the economic efficiencies of greater equality.

In the environmental sphere, investments in clean energy contribute towards reducing environmental degradation, pollution and the deterioration of natural capital. They reduce greenhouse gas emissions and local air contaminants, and contribute to the improvement of urban air quality and human health. In terms of health, investments in low-carbon energy for the transport sector are particularly important. The transport sector is the largest consumer of energy in Brazil (EPE, 2019). Investments in this sector can contribute to reducing the incidence of respiratory and cardiovascular diseases, cancer and reproductive disorders associated with urban pollutants (WHO, 2011), thus increasing the efficiency of public spending on health in the long run.

The menu of options for sustainable energy is extensive and has expanded with rapid technological development, including non-conventional renewable sources (photovoltaic, wind, sea, hydrogen, etc.), advanced fuels (e.g. second-generation ethanol, aviation biokerosene, renewable electrofuels), smart grids, energy efficiency, etc. There is no single ideal combination of these options, as each situation is unique and particular. In the context of the Big Push for Sustainability, it should be noted that investments ought to be complementary and coordinated towards the construction of a more sustainable, resilient and low-carbon energy mix, which is also more inclusive while promoting the systemic competitiveness of the economy. These examples of clean energies illustrate the growing relevance of electrification, connectivity and digitalization in the energy sector, and indicate that the industry is expected to undergo major changes in the coming years.

In this context, investing in innovation for renewable energies means a lot more than simply not falling behind this new technology wave. As stressed throughout this chapter, investments in ST&I are an essential component of the Big Push for Sustainability, because, among other factors, it is these investments that will provide technical solutions that match the reality of the country. In particular, it is the investments in this area that will allow the country's achievement and maintenance of socioeconomic benefits (in addition to environmental ones). Many of the socioeconomic co-benefits of investing in low-carbon energy will only be made possible if the country simultaneously accelerates its investment in research, development and demonstration to reinforce, update and expand its domestic technological and innovative capabilities. Finally, investments in ST&I for sustainable energies may significantly contribute to accelerating and lowering the costs of building a sustainable energy mix in Brazil.

Brazil and the world are at a crossroads. It is clear that today's dominant development styles have not been able to meet people's aspirations for jobs, better living conditions, health, education and healthy environment, among others. We live at unique times, in which there is a very narrow window of opportunity to effectively keep average global warming below 2° C, in order to contain the worst effects of climate change, and restore natural capital so as to avoid exceeding planet's limits.

On the one hand, inaction will deepen structural gaps in the current development style, including poverty, territorial and social inequalities, low productive diversification, structural heterogeneity, external vulnerability, etc. On the other, facing this crisis may offer opportunities to effect progressive structural changes, coordinated and guided by a Big Push for Sustainability that could transform production and consumption structure. By expanding a country's technological capabilities, the Big Push for Sustainability will contribute to the achievement of resilient, low-carbon and healthy solutions and to a more diversified and competitive role in the international market, laying the foundations for more and better social policies. The Big Push for Sustainability can be a driving force behind the urgent economic recovery that lies ahead of us, while supporting the construction of a style of sustainable development that protects the economy and people from other shocks and crises in the future. The challenges ahead are not negligible, but the cost of inaction and the potential benefits expected at the end of this process can certainly outweigh this effort. The Energy Big Push Brazil effort is a decisive step in this direction.

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II. Overview of energy RD&D investments in Brazil

A. Background

1. Scope and methodology

The EBP project is structured around four lines of action, presented in the Introduction to this document. This chapter is based on the final report on Axis 1, entitled "Overview of energy innovation investments in Brazil: Data for an energy big push," which can be consulted for additional details on the methodology, definitions and concepts adopted, as well as detailed results and discussions. Axis 1 is based on the premise that what cannot be measured cannot be managed. Therefore, its main objective is to develop a process for collecting, structuring, managing and analysing data on investments in energy research, development and demonstration (RD&D) in Brazil.

This study has sought to organize and systematize data with a view to offering a better understanding of the volume, focus and main characteristics of RD&D expenditures in the energy sector, which can offer relevant input for decision makers and other stakeholders to design systematic strategies and policies aimed at driving investment in that area. It is important to highlight the methodological contribution offered by the EPE, which developed a first database of public and publicly-oriented investments in research and development (R&D) between 2018 and 2019. The EPE used the International Energy Agency (IEA)'s classification applied to the databases of the Brazilian Electricity Regulatory Agency (ANEEL), the National Agency for Petroleum, Natural Gas and Biofuels (ANP) and the National Bank for Economic and Social Development (BNDES) for the year 2018. That first initiative was expanded through the Energy Big Push (EBP) project, which has incorporated additional data sources and added other years to the series.

The scope of the work included government data sources referring to public and publicly-oriented spending in R&D. This focus has allowed to capture a good part of energy-innovation investment in Brazil, since a significant extent of innovation expenditures in the energy sector is bound by provisions in energy concession legislation. In addition, this scope provides a way of incorporating structured and easily accessible data that captures public and private investment in innovation. Therefore, the analysis presented herein is based on RD&D projects funded and/or delivered by the federal government and other public bodies, in addition to RD&D projects funded by private companies in accordance with the research, development and innovation (RD&I) clause included in concession contracts (i.e. projects regulated by the ANP and ANEEL).[1] The latter investments are classified as publicly oriented.

The mapping exercise described above revealed that, although most of the analysed data sources are structured, they are fragmented into different bodies that produce and hold information according to their own spending or regulatory authority. This study has used data under the responsibility of the following organizations: the Ministry of Science, Technology and Innovations/National Science and Technology Development Fund (MCTI/FNDCT); the Funding Authority for Studies and Projects (FINEP); the National Council for Scientific and Technological Development (CNPq); ANEEL; ANP; BNDES; the National Nuclear Energy Commission (CNEN), and the São Paulo State Research Foundation (FAPESP).

The research carried out under EBP Axis 1 in 2019 involved the collection of structured and unstructured data, and the treatment of these data to generate a unique database of comparable public and publicly-oriented investments made between the years 2013 and 2018. Energy RD&D projects were identified and selected in each of the databases. After this selection, each project was allocated according to the IEA's classification of energy technology groups contained in the report "IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics" (IEA, 2011).

The classification of RD&D projects into groups of energy technologies adopted in this work includes 7 categories on a first level, and 30 subcategories on a second level, referring to groups of energy technologies, as can be seen in table II.1. The adoption of this classification enables international comparisons with several countries already mapped by the IEA, providing an important benchmark for Brazil, since the main reference adopted by the IEA is the Frascati Manual itself (OECD, 2015).

Table II.1
Categories of energy technology groups used for a two-level classification criterion (digit 1 and digit 2)

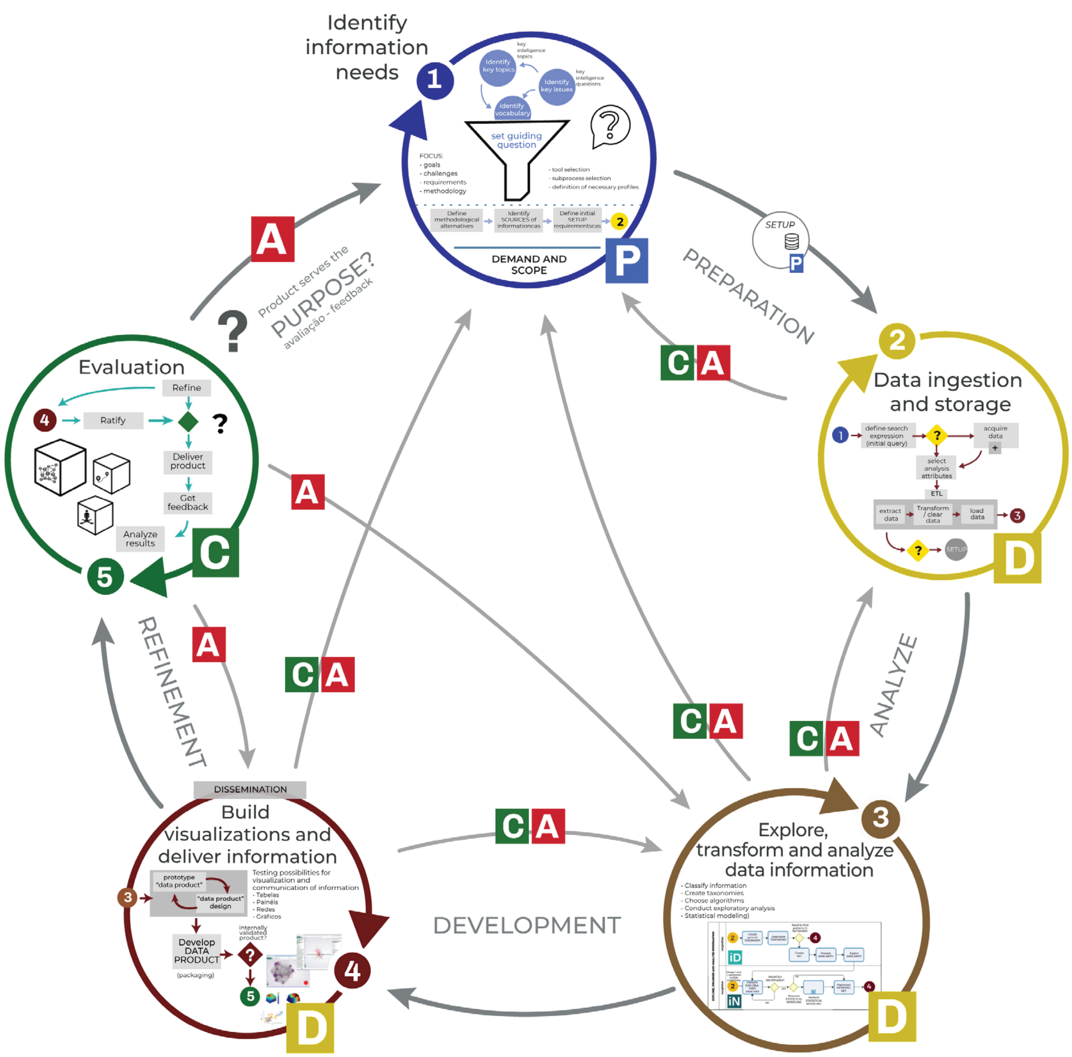
Digit 1	Energy Technology Groups	Digit 2	Subcategories
1	Energy Efficiency	1.1	Energy efficiency technologies applied to industry
		1.2	Energy efficiency technologies applied to residential and commercial buildings
		1.3	Energy efficiency technologies applied to the transport sector
		1.4	Other energy efficiency technologies
		1.9	Unallocated energy efficiency
2	Fossil Energy Sources: Oil, Natural Gas and Coal	2.1	Oil and gas
		2.2	Coal
		2.3	Carbon dioxide (CO2) capture and storage
		2.9	Unallocated fossil fuel technologies
3	Renewable Energy Sources	3.1	Solar energy
		3.2	Wind energy
		3.3	Ocean energy
		3.4	Biofuels (incl. liquid biofuels, solid biofuels and biogases)
		3.5	Geothermal energy
		3.6	Hydroelectricity
		3.7	Other renewable energy sources
		3.9	Unallocated renewable energy sources
4	Nuclear Fission and Fusion	4.1	Nuclear fission
		4.2	Nuclear fusion
		4.9	Unallocated fusion and fission
5	Hydrogen and Fuel Cells	5.1	Hydrogen
		5.2	Fuel cells
		5.9	Unallocated hydrogen and fuel cells
6	Other Energy Generation and Storage Technologies	6.1	Electric power generation
		6.2	Electricity transmission and distribution
		6.3	Energy storage (non-transport applications)
		6.9	Unallocated generation and storage technologies
7	Other Cross-cutting Technologies	7.1	Energy system analysis
		7.2	Basic energy research that cannot be allocated to a specific category
		7.3	Other

Source: Created by the authors based on International Energy Agency (IEA), *IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics*, Paris, 2011.

[1] The RD&I clause is a mandatory clause for oil and natural gas exploration, development and production contracts (ANP, 2019). In the case of ANEEL, Law No. 9,991 of July 24, 2000 determines that concessionaires and permit holders of public electricity distribution services are obliged to apply, annually, the amount of, at least, seventy-five hundredth percent of its net operating revenue in research and development of the electricity sector.

The data analysis method was inspired by the strategic intelligence meta-process developed by the Center for Strategic Studies and Management (CGEE), also known as the Intelligence Cycle. The Intelligence Cycle is described in diagram II.1.

Diagram II.1
Strategic intelligence meta-process in science, technology & innovation



Source: Center for Strategic Studies and Management (CGEE), "Desenho e detalhamento do primeiro nível do metaprocesso Inteligência Estratégica em CTI", *Modelagem e Automação de Processos Finalísticos*, Brasília, 2017.

During step 1 of the Intelligence Cycle, information needs were identified, and the data product was defined. In step 2, data was collected and processed. The databases maintained by the government, in which investments are classified as public or publicly oriented, were mapped and collected. After the collection and initial treatment of structured data, an R language algorithm was used to identify RD&D projects related to energy, and to classify each one according to its category and subcategory. In addition, each project's full cost was distributed over the years, based on the global budget contracted (when available) and the term of the project (using information available in the databases). In steps 3, 4 and 5, the information generated in step 2 was analysed. After validating the data with all partners involved, spreadsheets and graphics were produced.

2. Relevance in the context of the Big Push for Sustainability

EBP Axis 1 is directly aligned with the Big Push for Sustainability approach (see Chapter I), as it provides key data and information on the current framework for investment in innovation in clean energy, its main trends, and the areas that may become the focus for public policies. In addition, the results generated (not only the estimates, but mainly the method chosen for data collection, treatment, management and analysis) represent an important tool to monitor the evolution of these investments. It offers input for the improvement of policies aimed at investment acceleration, serving as a thermometer for a big push for low-carbon energies in Brazil. Still in line with the Big Push for Sustainability (ECLAC/FES, 2019), one can understand the importance of coordinated and targeted public policies to attract private investment in this area, given the large volume of public and publicly-oriented investments.

A clear trend can be observed in developed countries. After a period of more intense public investment in RD&D and the implementation of incentive mechanisms to foster private investment, there is now evidence of increased engagement of the private sector in technology development (Santos, 2015). This type of impact would suggest that the public investment and incentive mechanisms put in place may have led to the development of national technological, innovative and production capabilities. Such capabilities are key to the development of a national energy production chain, and to ensure that the socioeconomic benefits of investing in sustainable technologies may be retained by that country, as discussed in Chapter I.

National energy plans and climate plans and commitments, such as the Nationally Determined Contribution (NDC), voluntarily submitted by the Brazilian government under the Paris Agreement, underline the importance of investing in low-carbon energy in order to guarantee the supply for future demand within a trajectory of sustainable development with low greenhouse gas emissions. In this context, accelerating investments in clean energy RD&D can contribute to Brazil's energy security and sovereignty by building the necessary capabilities for the country to expand access to clean energy at fair prices. In addition, these investments would also contribute to achieving the commitments made in the Brazilian NDC for the energy sector in a less costly manner, since technology development seeks to increase efficiency and reduce costs. However, it is noted that Brazil is less dependent on fossil sources than the average found among developed and developing countries. Yet, in order to guarantee clean and sustainable energy security in the long term, coordinated policies and incentive mechanisms will be essential to promote energy transition while meeting the targets of the seventh Sustainable Development Goal (SDG) of the 2030 Agenda (UN, 2015), which drive the analysis of RD&D investments in this study.

Good data inform good decisions. Thus, the work carried out under Axis 1 seeks to overcome the challenge of safely reporting what types of energy solutions are being supported and developed in Brazil. This will facilitate the identification of bottlenecks and inform decision-making, while supporting the continuous development of RD&D in strategic areas, and highlighting the opportunities to reduce technological dependence and increase exports of low-carbon technologies based on Brazil's capabilities. All of this evidence-based knowledge is able to support coordinated decisions for a big push for sustainability in the country's energy sector, contributing to a more economically, socially and environmentally sustainable development trajectory. Particular attention may be given to ensuring that data collection and tracking efforts are carried out regularly to provide decision makers with updated information and a robust base of evidence.

B. Main findings

1. Data source

The data used in this effort to map RD&D investments in energy technologies have different natures and origins. Some derive from federal government budget allocations (either reimbursable or non-reimbursable), while others come from laws and regulations that establish RD&D investment as a requirement for concession contracts in the electricity and oil and gas sectors.

Table II.2 presents the main data sources —all from public authorities— analysed in this work. This table also provides information on the funding sources (whether it comes from the federal budget or private companies); the executing entities; the nature of the investment flow; and the type of investment for the purposes of this work —both for public and publicly-oriented investments.

Table II.2
RD&D data and funding sources, and their characterization

Data source	Funding source	RD&D executing entity	Nature of flow	Investment type
FINEP	FNDCT	STI (Science and Technology Institution)	Transfer	Public Investment
	FINEP	Private company	Loan	
CNPq	FNDCT	STI	Transfer	Public Investment
	Other			
MCTI	Federal budget	CNEN	Internal execution	Public Investment
	FNDCT	STI	Transfer	
ANEEL	Company	Company itself	Internal execution	Publicly-oriented investment
		STI	RD&D procurement	
		Another company		
ANP	Company	Company itself	Internal execution	Publicly-oriented investment
		STI	RD&D procurement	
		Another company		
BNDES	BNDES	Company	Loan	Public Investment
		STI	Transfer	Public Investment
		Another company		
FAPESP	São Paulo State Tax Revenue	STI	Transfer	Public Investment

Source: Created by the authors.

2. Estimated investments in energy RD&D in Brazil

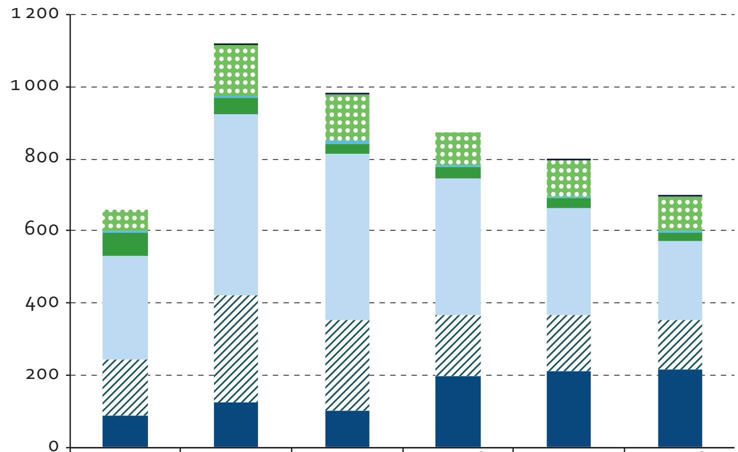
The results of the data analysis of public and publicly-oriented investment projects in energy RD&D (using the proposed method) enabled to produce three estimates based on different premises, as described below.

Public investments in energy RD&D

The preliminary estimate obtained through this study provides an overview of Brazilian public investments in energy RD&D in all categories of the study. It was based on data provided by the following institutions: MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and Siga-Brasil (for data on investments made by the CNEN).

Figure II.1 shows the sum of public investments in energy RD&D by technology category (digit 1, as per table II.1). Most public investments in RD&D are focused on renewable energy technologies, followed by fossil fuels, energy efficiency and other generation and storage technologies.

Figure II.1
Public energy RD&D investments per year by energy category in Brazil
(Millions of constant reais (2018))



	2013	2014	2015	2016	2017	2018
Other crosscutting technologies	0.00	0.03	0.04	0.00	0.01	0.01
Other power and storage technologies	60.24	140.97	131.23	89.51	100.84	95.53
Hydrogen and fuel cells	4.98	5.51	6.31	6.37	5.26	6.13
Nuclear energy	59.89	47.56	30.28	31.20	23.87	23.68
Renewable energies	290.36	502.02	461.27	379.70	297.60	216.98
Fossil fuels	153.24	294.28	248.49	169.24	157.77	137.74
Energy efficiency	89.46	126.26	102.91	196.21	209.82	215.93

Source: Created by the authors based on data from MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and Siga-Brasil.

The total amount of public investment in energy RD&D has seen a downward trend since 2014, when it peaked with over R$ 1 billion in 2018 values. This decline is due to some factors, among them the significant budget sequestration imposed on FNDCT in recent years, and the economic crisis that the country has been facing since 2014. The FNDCT is one of the main RD&D funding sources in Brazil.

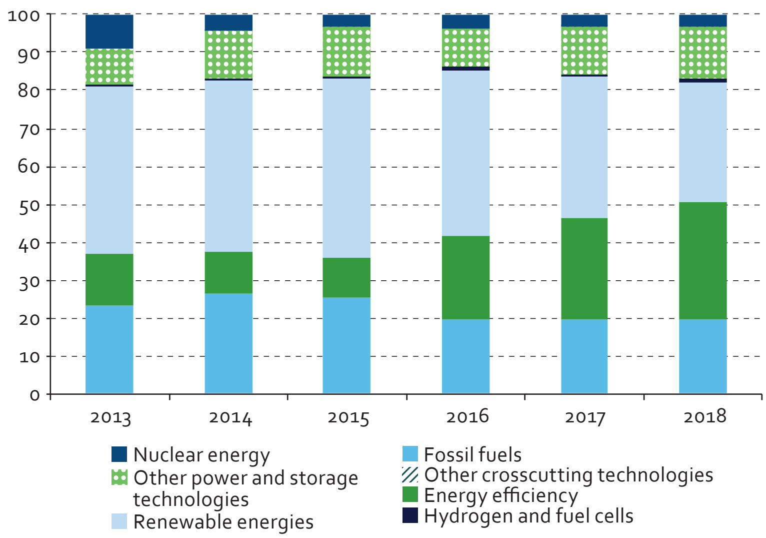
From 2013 to 2018, energy efficiency and hydrogen/fuel cell technologies were the only ones that maintained an upward trend in relation to the volume of public investments year on year (despite their low relevance compared to other categories). With the fall in investments during the analysed period, particularly investments in renewable energies and fossil fuel technologies, the overall investment in energy efficiency technologies is close to the amounts destined to other sources, as noted in figure II.2.

Figure II.3 shows a percentage comparison between RD&D projects focused on low-carbon technologies[2] and other technologies.[3] The vast majority of public RD&D expenditures are linked to low-carbon technologies, which demonstrates the alignment of public investments with climate policies. However, the fall in overall investment may jeopardize many studies on low-carbon technologies currently being developed in the country.

[2] Categories classified according to IEA standards, with all subcategories within categories 1, 3, 4, 5, 6 and 7, and subcategory 2.3 within category 2.

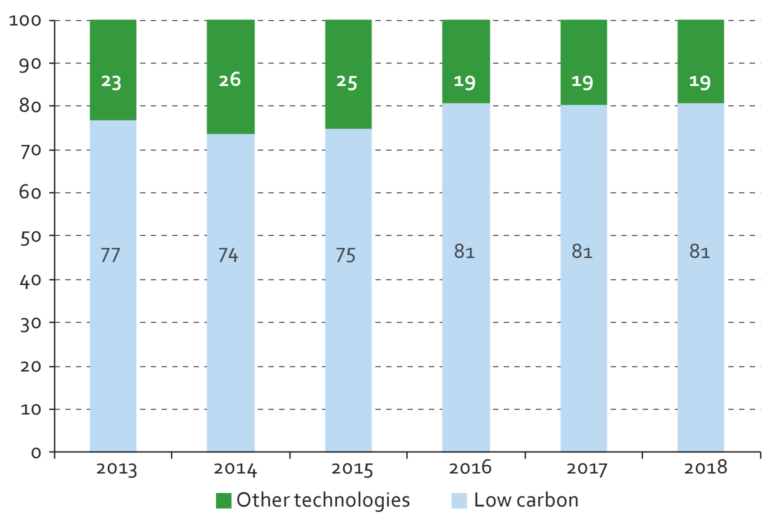
[3] Categories classified according to IEA standards, with subcategories 2.1 and 2.2 within category 2.

Figure II.2
Shares of energy categories in public expenditure on energy RD&D per year
(Percentages)



Source: Created by the authors based on data from MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and Siga-Brasil.

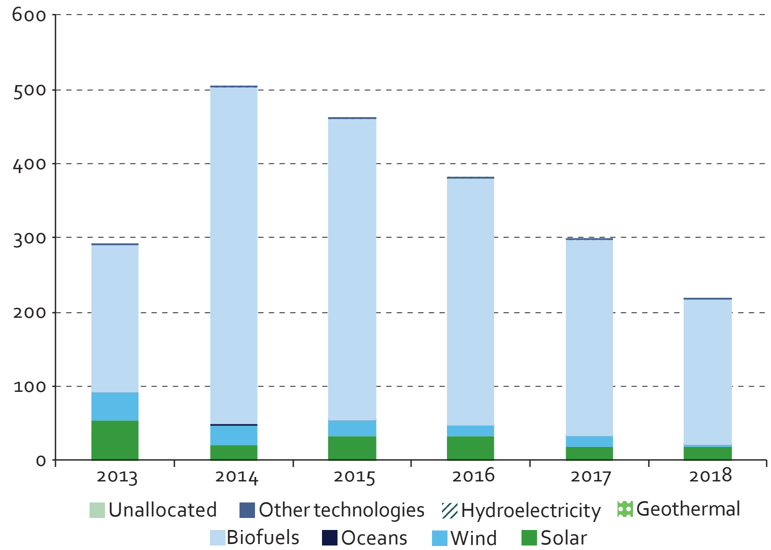
Figure II.3
Shares of low-carbon and other energy technologies in public expenditure on energy RD&D per year
(Percentages)



Source: Created by the authors based on data from MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and Siga-Brasil.

Figure II.4 shows the growth of public investments in renewable energy RD&D by subcategory between 2013 and 2018. RD&D projects in the area of biofuels add up to a total of R$ 1.8 billion for the entire period of analysis. This is notably the category that received the largest volume of investments. The fact that Brazil has a very strong biofuels sector, and that the country's NDC includes a commitment to increasing the share of biofuels in its energy mix by 2030, is consistent with the volume of public RD&D investments aimed at this sector. However, reflecting on the amounts destined for RD&D in other renewable technologies (solar, wind, oceans, hydroelectricity and geothermal), the latter are marginal when compared to those destined for biofuel RD&D.

Figure II.4
Amount of public investments in renewable energy RD&D
(Millions of constant reais (2018))



Source: Created by the authors based on data from MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and Siga-Brasil.

Despite the significant increase in the share of renewable energies in Brazil's energy mix, which grew from 39% in 2014 to 45% in 2018, it is important for the country to resume its previous level of investment in renewable energies to boost a sustainable energy transition, strengthening its capabilities and reducing its dependence on technology imports. This resumption of investments in RD&D ought to be coordinated and balanced according to national priorities, and sustained in the long run so that new ideas and emerging technologies may continue to be promoted until they reach the market. The country needs to maintain its recent trajectory, which allowed the biofuels share to grew from 17% to 23% in the transport mix, and wind and solar power to reach 8% of the internal supply of electricity, with respectively 15 GW and 2.4 GW installed capacity (EPE, 2019).

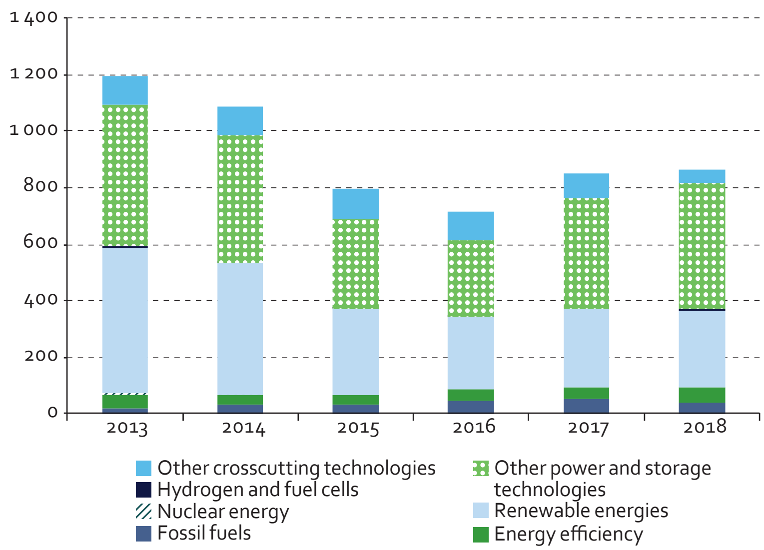
Publicly-oriented investments in energy RD&D

The estimate of publicly-oriented investments found through this study provides an overview of these investments in energy RD&D according to the classification adopted by the IEA. Publicly-oriented investments are regulated by ANEEL and the ANP, and the analysis was based on public data available on these agencies' websites.

Figure II.5 shows the sum of publicly-oriented investments in energy R&D, regulated by ANEEL, by energy technology category (as per table II.1).

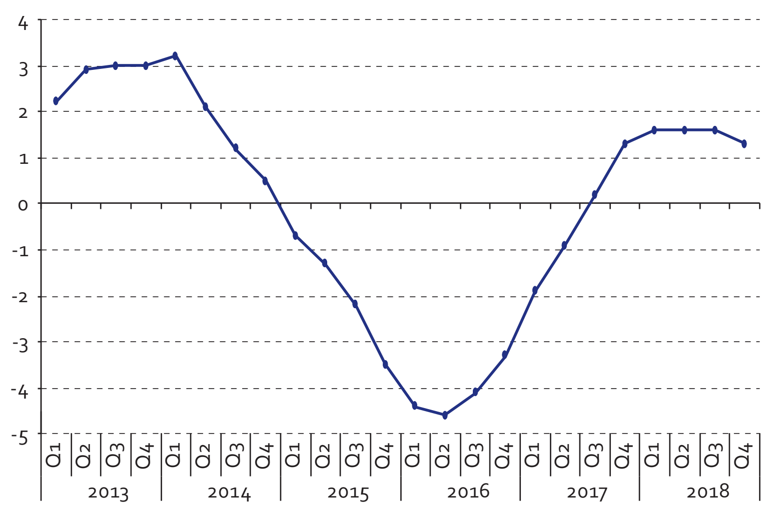
Most of the investments in RD&D made under the ANEEL programme are focused on renewable energy technologies and other power and storage technologies. As R&D resources are linked to the annual turnover of companies in the sector, the U-curve shown in the chart reflects the crisis and economic retraction that the country experienced from 2014 to 2016, as well as the beginning of its recovery in 2017, which raised revenues in the sector and, consequently, increased R&D spending. This curve is very similar to the Brazilian Gross Domestic Product (GDP) curve for the same period, as can be seen in figure II.6.

Figure II.5
Publicly-oriented energy RD&D expenditures regulated by ANEEL
(Millions of constant reais (2018))



Source: Created by the authors based on ANEEL data.

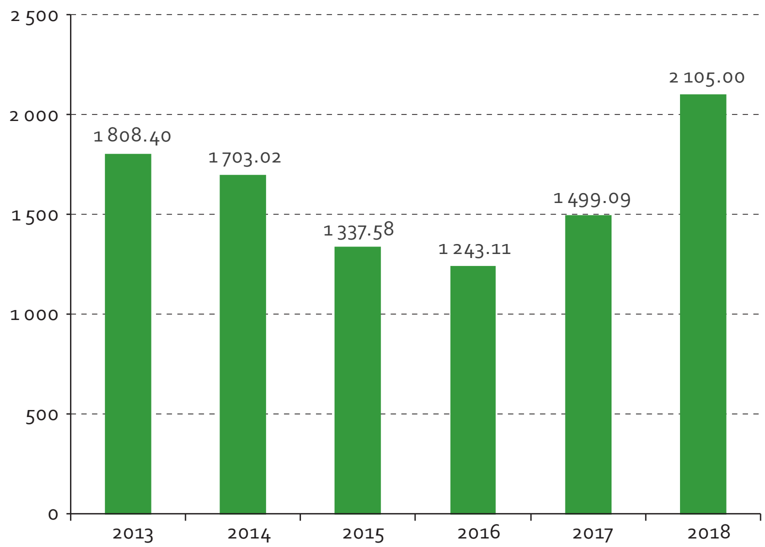
Figure II.6
Percentage change in Brazilian GDP from 2013 to 2018
(Percentage rates (cumulative over four quarters))



Source: Created by the authors based on Brazilian Institute of Geography and Statistics (IBGE), "Sistema de Contas Nacionais Trimestrais" [online] https://www.ibge.gov.br/estatisticas/economicas/contas-nacionais/9300-contas-nacionais-trimestrais.html [Accessed on 30 April 2020], 2020.

As explained in the EBP Axis 1 technical report, data on ANP-regulated projects were made available in aggregate form. With only aggregated data, the assumption that all ANP-regulated investments focused on fossil fuels was adopted. This was a necessary simplification to report the data, although we recognize that part of these resources may have been invested in other categories, such as energy efficiency (category 1), biofuels (category 3.4) and carbon use and storage technologies (category 2.3). Figure II.7 shows the evolution of expenditures made for ANP-regulated R&D projects.

Figure II.7
Publicly-oriented energy RD&D expenditures regulated by the ANP
(Millions of constant reais (2018))



Source: Created by the authors based on ANP data.

Once again, a U-shaped curve illustrates the total volume of R&D expenditures, which is also similar to the GDP curve for the period, consistent with the fact that the RD&I clause in contracts for exploration, development and production of oil and gas represents a percentage of companies' annual gross revenue. The variation in national GDP, the rise in exports due to higher international prices of oil and oil products, and the growth in gasoline exports boosted the gross revenues of companies operating in this sector in 2018, increasing the volume of regulated RD&D activities.

The strong relationship between spending on RD&D and GDP indicates that the crisis caused by the COVID-19 pandemic, which is still unfolding, tends to have adverse impacts on energy innovation.

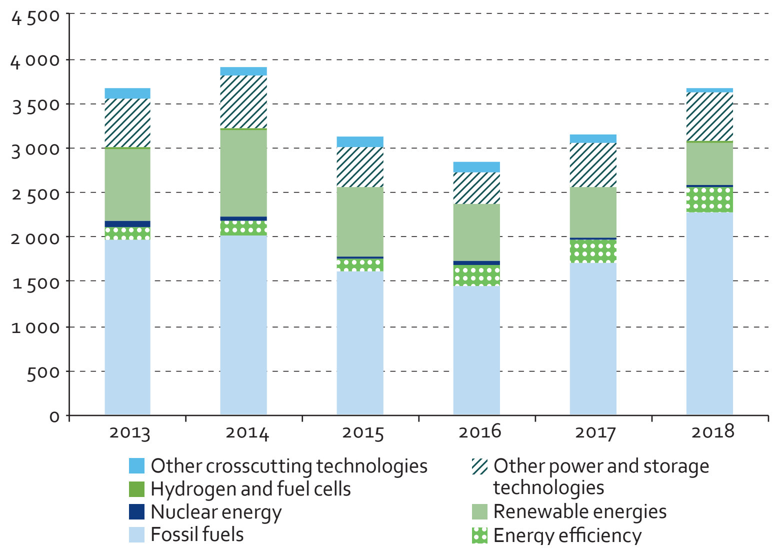
Public and publicly-oriented investments in energy RD&D

A global estimate of public and publicly-oriented investments provides an overview of the main investments made in energy RD&D in Brazil, classified according to IEA categories. Public and publicly-oriented investments include data provided by the following organizations: MCTI/FNDCT, ANP, ANEEL, BNDES, FINEP, CNPq, FAPESP and Siga-Brasil (for data on investments made by the CNEN). Figure II.8 shows the sum of public and publicly-oriented investments in research, development and demonstration by energy technology category (as per II.1) from 2013 to 2018.

Most investments in RD&D, in this case, are focused on fossil fuel technologies. This can be explained by the importance of RD&D projects associated with contractual obligations for businesses in the oil and gas sector, regulated by the ANP.

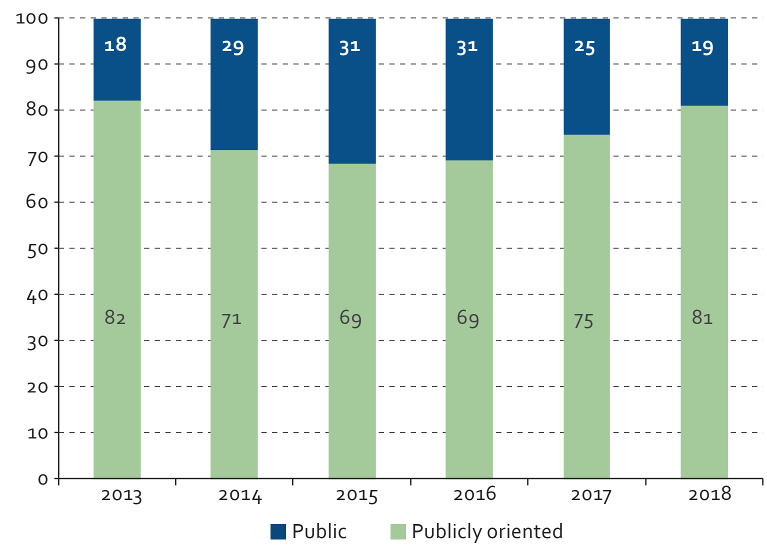
Figure II.9 shows the percentage share of RD&D expenditures in public and publicly-oriented investments. From this chart, one can note very clearly how important ANEEL- and ANP-regulated RD&D programmes actually are for fostering energy innovation in Brazil. In some years between 2013 and 2018, these programmes accounted for over 80% of all energy RD&D investments in the country, according to the dataset selected for this study.

Figure II.8
Amount of public and publicly-oriented investments in energy RD&D per year by energy category in Brazil
(Millions of constant reais (2018))



Source: Created by the authors based on data from ANEEL, ANP, MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and Siga-Brasil.

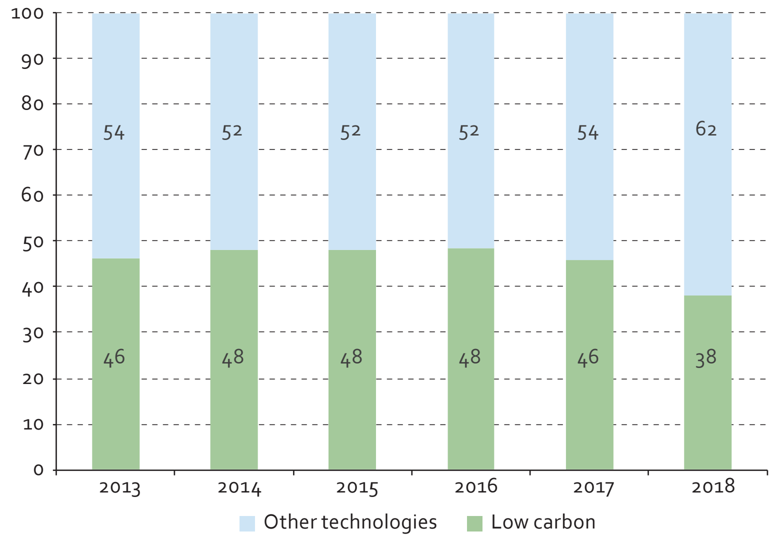
Figure II.9
Share of public and publicly-oriented expenditures in energy RD&D investments
(Percentages)



Source: Created by the authors based on data from ANEEL, ANP, MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and Siga-Brasil.

Figure II.10 shows a percentage comparison between public and publicly-oriented investments in RD&D projects aimed at low-carbon technologies and other technologies. The higher percentage share of Other Technologies is due to the weight of investments in ANP-regulated projects, classified under category 2 (fossil fuel technologies group).

Figure II.10
Shares of low-carbon and other energy technologies in public and publicly-oriented expenditure on energy RD&D per year
(Percentages)



Source: Created by the authors based on data from ANEEL, ANP, MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and Siga-Brasil.

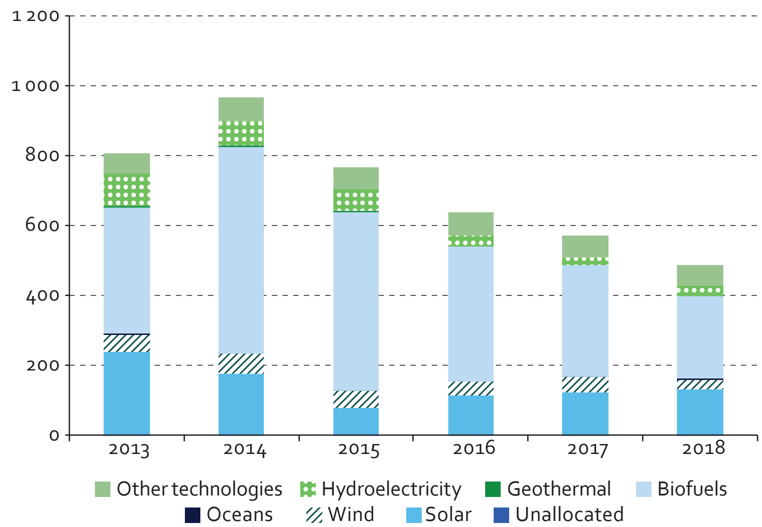
It is important to note that, although all ANP projects were classified as Other Technologies (non-low-carbon), it is a fact that part of these investments may be destined to projects in low-carbon energy categories, as mentioned above. Due to the limited data available, the Other Technologies category is overestimated for the series, and efforts to further disaggregate these data should be undertaken to obtain a better overview of the distribution of such investments.

Figure II.11 shows the evolution of public and publicly-oriented investments in renewable energy RD&D between 2013 and 2018. Biofuels R&D projects add up to a total of R$ 2.4 billion for the entire period of analysis, appearing as the category that received the largest amount. Solar (3.1), wind (3.2) and hydroelectric (3.6) power are the renewable energy technologies that received the most investments after biofuels.

Among all public and publicly-oriented investments in RD&D, those in renewable energy generation technologies achieved their largest share in 2014, with a total volume of R$ 966 million in 2018 values. This might help to explain the remarkable progress in biofuels, bioelectricity, wind and solar power since 2014. In the following years, resources for renewable energy technologies fell year after year, mainly due to the reduction in FNDCT funds. This drop may have a big impact on the R&D of new ideas and emerging technologies, since they need coordinated and constant investments at all stages of their development, from basic research to commercialization, as discussed in Chapter IV.

It is important to stress that there are still many improvements to be made in the treatment and analysis of data, and in the consideration of other data sources for RD&D projects carried out in Brazil that are not included in this study. However, this overview, based on international classification standards, provides an opportunity for developing benchmark studies against OECD countries (Organization for Economic Cooperation and Development). It also enables the identification of bottlenecks and opportunities, especially with regard to the coordination of medium- and long-term RD&D investment policies, ensuring a greater balance both in the amount of investments per year, and in the distribution of these investments in projects of strategic interest to the country, with a view to fostering a big push for sustainability in the energy sector.

Figure II.11
Amount of public and publicly-oriented investments in renewable energy RD&D
(Millions of constant reais (2018))



Source: Created by the authors based on data from MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and Siga-Brasil.

C. Improvement opportunities and recommendations

The quality of the statistics and recommendations produced by this study depends directly on the quality and volume of data collected, as well as on the accuracy of the method of analysis (developed with search terms defined by experts in the area, as described in detail in the technical report on EBP Axis 1). In order to expand access to and the robustness of the results produced, some recommendations for future studies are presented below:

(i) Reviewing and improving the method of analysis, especially with regard to the initial treatment of databases maintained by public agencies, the search terms used, and the expert analysis of interim spreadsheets in order to check the consistency of the selected projects;

(ii) Creating a dashboard to display all processed, harmonized and analysed data, so as to facilitate access to such data and support decision-making and guidance related to policies and ongoing programmes in the area of energy RD&D;

(iii) Completing the missing information on regulated RD&D projects (particularly those regulated by the ANP), which may enable a more accurate classification of investments according to IEA categories;

(iv) Adding data from other federal organizations, especially the Ministry of Education and the Ministry of Agriculture;

(v) Mapping data at state level and by state-owned enterprises, and exploring methodological alternatives for surveying RD&D expenditures and refining their classification;

(vi) Reaching an agreement among all entities involved to ensure a regular flow of information;

(vii) Maintaining the process conducted by the EBP Axis 1 Working Group, which has been acting as a technical body for this survey, with the objective of developing more robust statistics and analyses of energy RD&D;

(viii) Supporting the sources responsible for the data in adding fields with specific information on RD&D projects to their data records, such as: energy technology categories, at least on 2 levels; RD&D stages (research and development project, or demonstration project); information on source of funds and budget profile year by year;

(ix) Supporting the institutions responsible for RD&D or RD&D data in Brazil in adopting more efficient and secure ways of recording information about projects and their executors, such as: energy technology categories according to IEA classification, on at least 2 levels; RD&D stages —whether it is a research and development, or a demonstration project (ideally information about the technology readiness level (TRL) of the technology in question); information on source of funds and budget profile year by year; and other information that may be essential for the management and inspection bodies responsible for RD&D programmes and projects;

(x) Conducting research on private-sector RD&D investments in Brazil (not involving the ANP and ANEEL) to check the possibility of a broader comparative analysis between public and private investments; and

(xi) Creating indicators to assess the impact of existing RD&D programmes and projects, both in the public and private sectors.

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III. Performance indicators for low-carbon energy technologies

A. Background

1. Scope

Effective energy solutions that take national circumstances into account are important and can benefit from the creation and adoption of tools aimed to support GBEP decision makers (2011). This chapter is based on the final report on Axis 2 of the Energy Big Push (EBP) project, entitled "Performance indicators associated with low-carbon energy technologies in Brazil: Evidence for an energy big push," which can be consulted for further details on the methodology, definitions, and concepts adopted in this work, in addition to presenting more detailed results and discussion. The work carried out under EBP Axis 2 consisted of a study that provides a set of indicators and presents the results of technical, economic, social and environmental variables and parameters in order to assess the performance of low-carbon energy technologies in Brazil. This exercise included mapping, surveying and organizing existing data and literature; analysing data and collecting information; and presenting a selection of performance indicators associated with low-carbon energy solutions and their respective values.

For the purposes of this study, low-carbon energy solutions are those defined by the International Energy Agency (IEA – IEA, 2011) under categories 1 – Energy efficiency; 3 – Renewable energy sources; 5 – Hydrogen and fuel cells; 6 – Other electricity and storage technologies; and 7 – Other cross-cutting technologies or research.

Based on this classification, the participants of the EBP Working Group 2 (WG2) selected technologies for specific sectors. The selection criteria considered, among other aspects:

- In terms of sector: current and future relevance of the sector with regard to economic performance, share of energy supply and demand, and environmental impacts (Brazil, 2015; EPE, 2018a; and Rathmann (org.), 2017);

- In terms of technology: potential for scale deployment in Brazil, future prospects for development and progression of learning curves, as well as the relevance for national energy policy and strategic development (EPE, 2018a and b; MME, 2018; Rathmann (org.), 2017); La Rovere et al., 2018; and MCTI, 2018).

The assessed technologies were (by sector):

- Centralized power generation: large hydroelectric power plants, small hydroelectric power plants, thermal power plants (forest biomass and sugarcane bagasse), solar photovoltaic power plants (PV), concentrated solar power plants (CSP), onshore and offshore wind power plants;
- Mini and micro power generation: thermoelectric (biogas from agricultural residues) and distributed solar photovoltaic systems;
- Transport: light-duty vehicles (LDV), buses and trucks, hybrid vehicles, battery electric vehicles (BEV), and internal combustion engine vehicles (ICE), when relevant; and
- Biofuels: sugarcane bioethanol, soy biodiesel, biogas (from municipal solid waste), and biokerosene.[1]

The indicators proposed to measure the performance of low-carbon energy technologies are classified into three major dimensions of sustainable development: environmental, economic, and social. A fourth cross-cutting pillar considers institutional feasibility.

Environmental pillar

Energy production generally leads to significant anthropogenic pressures on the environment, including climate change, local air pollution, deforestation, water consumption, land use, reduced water and soil quality, among others. Many of the environmental effects of energy-related activities are long-term and carry a degree of uncertainty. The environmental indicators include these aspects, as well as risks associated with human activity and natural disasters. The selected indicators are:

- Water use;
- Impacts on water quality and aquatic biodiversity;
- Land use;
- Impacts on soil quality and terrestrial biodiversity;
- Greenhouse gas (GHG) emissions;
- Non-GHG emissions; and
- Vulnerability and risks.

Technical-economic pillar

This pillar primarily assesses the associated production costs for different technologies, an underlying aspect that determines market allocation decisions for energy technologies. It also includes other aspects, such as learning curves, upstream and downstream effects on production chains, energy efficiency and diversity. The suggested indicators are:

- Efficiency in energy conversion and use;
- Technology readiness level (TRL);
- Technology ownership;
- Capital expenditures for production (CAPEX);

[1] HEFA pathway: hydroprocessed esters and fatty acids.

- Operation and maintenance expenditures (OPEX);
- Total costs;
- Associated infrastructure requirements;
- Energetic diversification; and
- Supply chain readiness or capacity.

Social pillar

The social pillar indicators include income and job creation, which are both intrinsically related to stimulating economic growth and supporting public policies. However, they also ought to consider the potential impacts on the local population, workers and assets. These equity aspects can affect society's perception of energy production projects. The selected indicators are:

- Job creation;
- Income generation;
- Access to electricity;
- Population directly affected;
- Incidence of occupational injuries, diseases and mortality;
- Respect for indigenous and traditional communities; and
- Risks to cultural, historical and archaeological heritage.

Political-institutional pillar

Finally, there are a number of questions that are difficult to quantify or that have a more qualitative nature, but that need to be taken into account in any decision-making process, and in the final design of key energy policies (Vera and Langois, 2006). This is fundamentally the case of indicators that measure institutional feasibility and that make up the political-institutional pillar. According to IRENA (2014), one of the reasons why institutional feasibility tends to be assessed qualitatively is that this criterion does not measure success, but helps to explain the potential of a policy to be successful. Thus, results can also be more difficult to interpret, as they do not incorporate a benchmark against which assessments can be made. These challenges may make it more difficult to assess institutional feasibility than other criteria for which quantitative methods are more suitable. The chosen indicators are:

- Simplicity of environmental licensing process;
- Compatibility with energy policy and international agreements; and
- Compatibility with existing institutional, legal and regulatory frameworks.

2. Relevance in the context of a Big Push for Sustainability

Energy policy's environmental, social and economic implications should be considered holistically, and should be reflected in institutional arrangements. Policy makers and corporate strategy designers ought to measure and evaluate current and future effects of energy production and use on health, equity, the economy and the environment, among others. Therefore, it is important that policy and strategy decision makers understand the implications of selected environmental, social, economic and energy plans, programmes and projects, and their impacts on the definition of development styles (Vera and Langois, 2006). In this sense, indicators are useful for monitoring progress towards specific country targets and for identifying the factors that are most sensitive to policy changes. Any indicator will naturally depend on its purpose. The characteristics of such indicators include relevance to the users' needs, scientific validity, and practicality.

Indicators go beyond basic statistics to provide a deeper understanding of causal relationships in the energy-environment-economy-society nexus, and to highlight links that may not be evident from simple statistics. Taken together, indicators can provide a snapshot of the energy system as a whole, including interconnections and trade-offs among different dimensions of sustainable development, as well as long-term implications of current decisions and behaviours (Vera and Langois, 2006). In general, the indicators provide the right questions to be asked when assessing the effect of practices and policies aimed at meeting nationally defined goals for a country's development.

A good set of indicators can be extremely useful and helpful to decision makers, offering technical information on multiple dimensions of sustainable development. Informed decision-making undoubtedly enables better and more coordinated investments in research, development and demonstration (RD&D), as well as adequate incentive mechanisms for the promotion of low-carbon technologies that are appropriate to the national context, so as to foster a Big Push for Sustainability in Brazil.

The work carried out under Axis 2 is critical to enable an energy big push in Brazil, as it sheds light on the path to be taken. The Big Push for Sustainability approach focuses on maximizing the synergies and co-benefits of complementary low-carbon investments, leading to greater systemic efficiency in the development style; driving a virtuous circle of economic growth, job creation, development of production chains, reduction of environmental footprint and environmental impacts; and restoring the productive capacity of natural capital, all together and at the same time (see chapter I). A set of indicators that contemplate a wide spectrum of sustainable development dimensions is essential to identify potential investment synergies; quantify the impacts of alternative scenarios; monitor and follow up on the impacts of all investments made (and, indirectly, of implemented policies and strategies); and finally, assess and enhance the regulatory framework and incentive mechanisms so that they are effective in promoting investments for an Energy Big Push.

The information produced under Axis 2 can help to identify complementary technologies and sectors that could become the focus of a coordinated set of policies, in line with a Big Push for Sustainability, considering its potential to deliver multiple social, economic and environmental benefits. In the light of national aspirations, vocations, cooperation mechanisms and triple efficiency, which are the guiding pillars of a Big Push for Sustainability (see Chapter I), the indicators developed during this work can help to detect the appropriate combination —for the Brazilian context— of complementary and coordinated investments for the construction of a more sustainable, resilient and low-carbon energy mix. Such energy mix would also be more inclusive and able to promote the systemic competitiveness of the economy. In addition, this set of indicators can become a useful navigation tool for decision makers, as it allows continuous adjustments to the country's course of action towards the sustainable development model it aims to achieve.

B. Main findings

A quantitative assessment was carried out for 11 of the 26 indicators presented above. The selection of indicators took into account data applicability, availability and quality, as well as the importance of each indicator and the particularities of the Brazilian context. When applicable or relevant for comparison purposes, figures relative to conventional reference technologies that can potentially be replaced by low-carbon technological solutions will also be displayed (for example, natural gas thermoelectric plants and vehicles with fossil fuel internal combustion engines). Monetary indicators are presented in US dollars (USD), at constant 2018 values.[2]

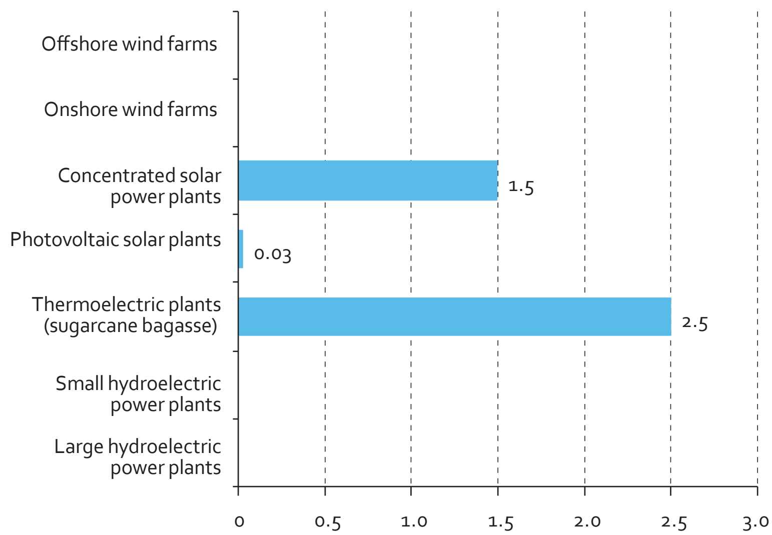
[2] Average exchange rate (2018): R$ 3.65/US$ 1 (Brazilian Central Bank, 2019).

1. Environmental pillar

Power generation

For biomass thermoelectric plants and concentrated solar power plants (CSP), water is directly used for cooling during the operation phase. In solar photovoltaic power plants (PV), the use of water is required mainly to clean the panels. Hydroelectric power plants (large or small) do not consume water directly, and any losses are due to the natural water cycle, i.e. evaporation from reservoirs. For onshore and offshore wind farms, no water is required (IRENA/WRI, 2018).

Figure III.1
Water use for centralized power generation technologies
(In m³/MWh)

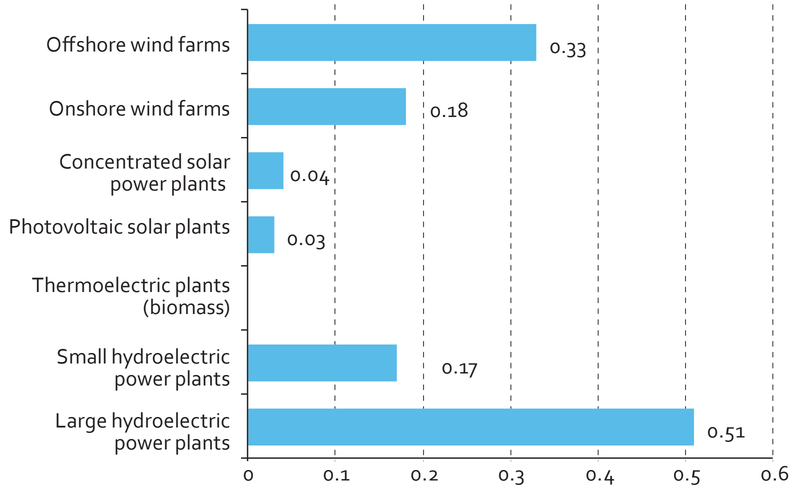


Source: Created by the authors based on National Water Agency (ANA), *Manual de Usos Consuntivos da Água no Brasil*, Superintendência de Planejamento de Recursos Hídricos (SPR), Brasília, 2019; and Bukhary, Saria, Sajjad Ahmad and Jacimaria Batista, "Analyzing land and water requirements for solar deployment in the Southwestern United States", *Renewable and Sustainable Energy Reviews*, Elsevier, vol. 82, 2018.

Electric power generation plants use land according to their installed capacity (facilities and equipment). In the case of hydroelectric power plants, flooded areas transformed into reservoirs are computed. For thermal power plants running on biomass, the land requirements associated with energy crops should be considered as well. For solar and wind power plants, the land requirements are relative to the installation and spacing of equipment (panels and turbines). For wind power, specifically, the spacing depends on turbine size and position; therefore, an average cost for existing projects was used as a reference.

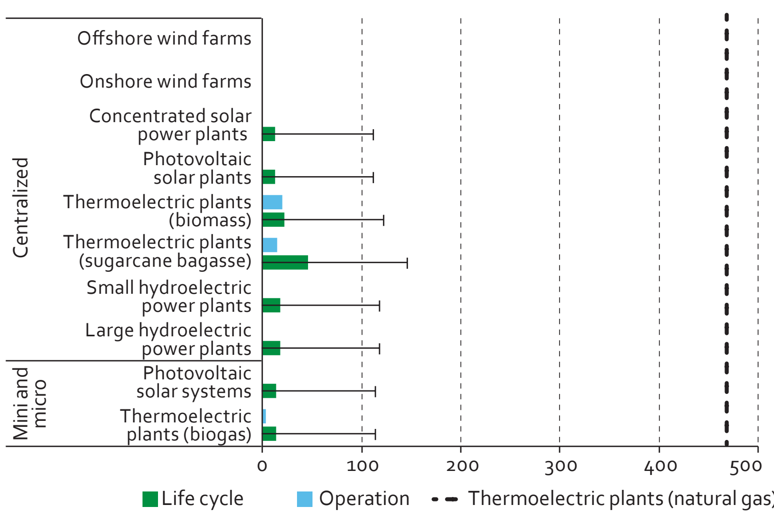
Some energy sources do not generate GHG emissions during operation. However, when considering their entire life cycle, emissions are not negligible. Thus, when available, data are shown for emissions during operation and the whole life cycle. Life-cycle GHG emissions are available for centralized power generation technologies in the IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (2006). For the sake of comparison, direct emissions from the operation of natural gas thermoelectric plants are also shown.

Figure III.2
Land use for centralized power generation technologies
(In km²/MW)



Source: Created by the authors based on Bukhary, Saria, Sajjad Ahmad and Jacimaria Batista, "Analyzing land and water requirements for solar deployment in the Southwestern United States", *Renewable and Sustainable Energy Reviews*, Elsevier, vol. 82, 2018; Musial, Walt et al. (2016), *Offshore Wind Energy Resource Assessment for the United States*, National Renewable Energy Laboratory (NREL), Golden, CO; Energy Research Office (EPE), *Nota Técnica EPE 026/2018 – Análise socioambiental das fontes energéticas do PDE 2027*, Rio de Janeiro, Ministério de Minas e Energia/Empresa de Pesquisa Energética (MME/EPE), November; and Simsek, Yeliz, David Watts and Rodrigo Escobar (2018), "Sustainability evaluation of Concentrated Solar Power (CSP) projects under Clean Development Mechanism (CDM) by using Multi Criteria Decision Method (MCDM)", *Renewable and Sustainable Energy Reviews*, vol. 93, October.

Figure III.3
GHG emissions from power generation technologies
(In gCO_{2e}/kWh)

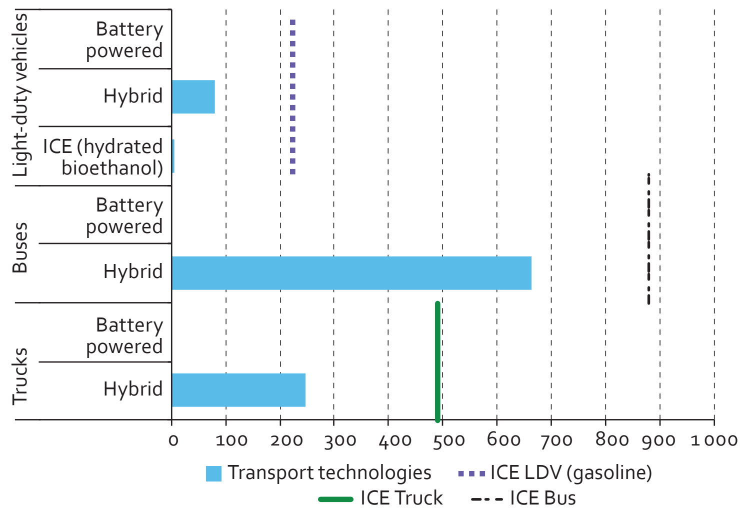


Source: Created by the authors based on Edenhofer Ottmar et al. (eds.), *Renewable energy sources and climate change mitigation: Special Report of the Intergovernmental Panel On Climate Change*, Cambridge, United Kingdom, IPCC, 2011; and Intergovernmental Panel on Climate Change (IPCC), *IPCC Guidelines for National Greenhouse Gas Inventories*, Prepared by the National Greenhouse Gas Inventories Program ", Eggleston, Simon et al. (Eds.), Institute for Global Environmental Strategies (IGES), Japan, 2006.

Transport

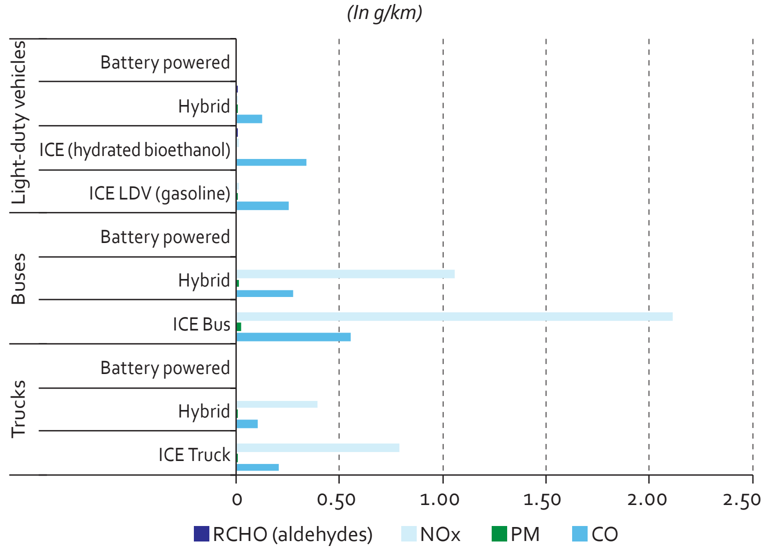
For transport technologies, the following premises were considered: hybrid vehicles require, on average, 50% less fuel than similar internal combustion engine (ICE) vehicles (be they trucks, buses, or light-duty vehicles–LDV); carbon dioxide (CO_2) emissions from vehicles fuelled with hydrated bioethanol (E100) are zero, taking the biomass life cycle into account; and tailpipe emissions from battery electric vehicles (BEV) are also zero. However, although the grid emission factor can be calculated in extended scope analyses, this approach was not chosen due to uncertainties regarding the grid emission factor. Although trucks and buses run on diesel, fuel consumption for trucks is lower than for city buses, mainly due to differences in driving patterns (e.g. frequent stops, urban traffic, etc.).

Figure III.4
GHG emissions from transport technologies
(In gCO_{2e}/km)



Source: Created by the authors based on International Renewable Energy Agency (IRENA), *Renewable Energy and Jobs: Annual Review 2019*, United Arab Emirates, June 2019.

Figure III.5
Non-GHG emissions from transport technologies
(In g/km)



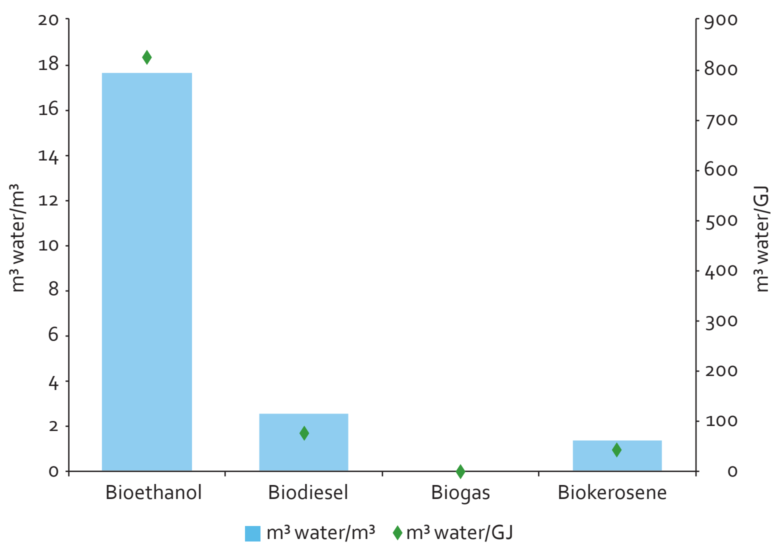
Source: Created by the authors based on International Renewable Energy Agency (IRENA), *Renewable Energy and Jobs: Annual Review 2019*, United Arab Emirates, June 2019.

The main air pollutants analysed for transport technologies were carbon monoxide (CO), particulate matter (PM), nitrogen oxides (NOx) and aldehydes. Among the fuels that were assessed, PM and aldehyde emissions are negligible. For ICE vehicles running exclusively on hydrated bioethanol, CO is the most significant pollutant. For hybrid diesel vehicles, NOx is the most important source of air pollution. For the sake of comparison, emissions from conventional ICE vehicles powered by gasoline and diesel are also displayed. For gasoline vehicles, CO is the most significant pollutant, but emissions are lower than for ICE vehicles using hydrated bioethanol; and for diesel vehicles, NOx is the most significant pollutant, especially for city buses.

Biofuels

The use of water for biofuel production accounts only for the processing steps during the industrial phase. Irrigation during the agricultural phase was not included due to a great diversity of crops, and the fact that Brazilian agricultural practices rarely rely on irrigation.

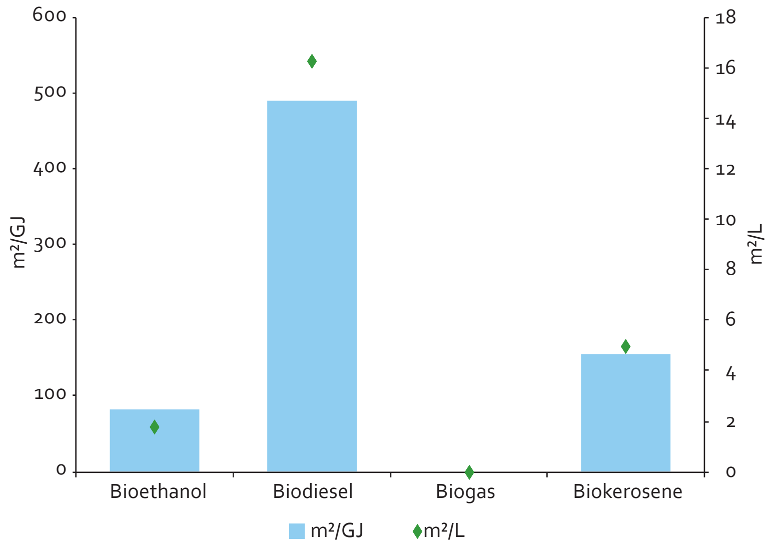
Figure III.6
Water use for biofuel technologies
(In m^3 water/m^3 and m^3 water/GJ)



Source: Created by the authors based on National Agency for Petroleum, Natural Gas and Biofuels (ANP), "RenovaCalc 2019" [online], www.anp.gov.br › images › Consultas_publicas › CP10-2018_Calculadora, 2019.

The use of land for the production of biofuels is mainly linked to agricultural crops used for the production of non-residual raw material. Biodiesel requires more land than bioethanol, because sugarcane has much higher productivity levels than soybeans, the main raw material for biodiesel in Brazil (approximately ten times as much). When comparing biodiesel with biokerosene, the difference is related to the fact that one ton of soybeans produces more biokerosene than biodiesel. However, the fact that biofuels are agricultural by-products should also be taken into account. In the case of soy or maize, for example, fuels are extracted simultaneously, without prejudice to the production of protein for food use. For biogas, land requirements are null, as waste is the source of raw material.

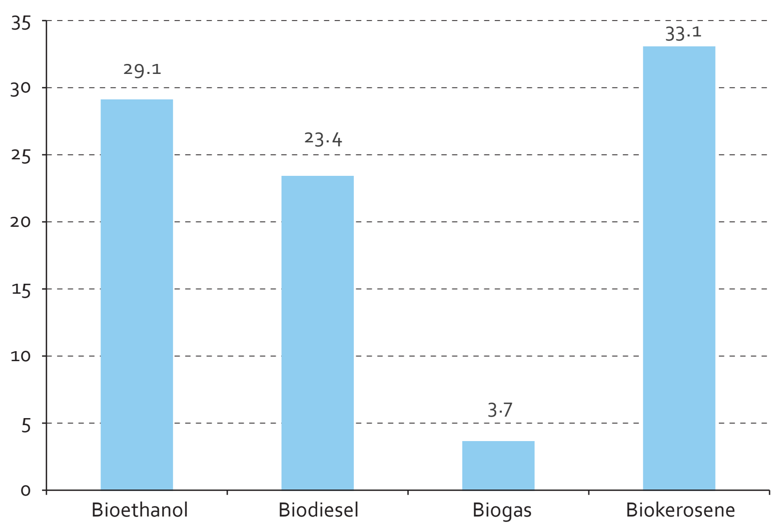
Figure III.7
Land use for biofuel technologies
(In m²/GJ and m²/L)



Source: Created by the authors based on National Agency for Petroleum, Natural Gas and Biofuels (ANP), "RenovaCalc 2019" [online], www.anp.gov.br › images › Consultas_publicas › CP10-2018_Calculadora, 2019.

GHG emissions from biofuels refer only to the agricultural and industrial processing phases, as combustion emissions have already been accounted for under transport. Emissions from crop or waste burning in the fields are not taken into account, as these practices are nearly extinct.

Figure III.8
GHG emissions from biofuel technologies
(In gCO_2e/MJ)



Source: Created by the authors based on National Agency for Petroleum, Natural Gas and Biofuels (ANP), "RenovaCalc 2019" [online], www.anp.gov.br › images › Consultas_publicas › CP10-2018_Calculadora, 2019.

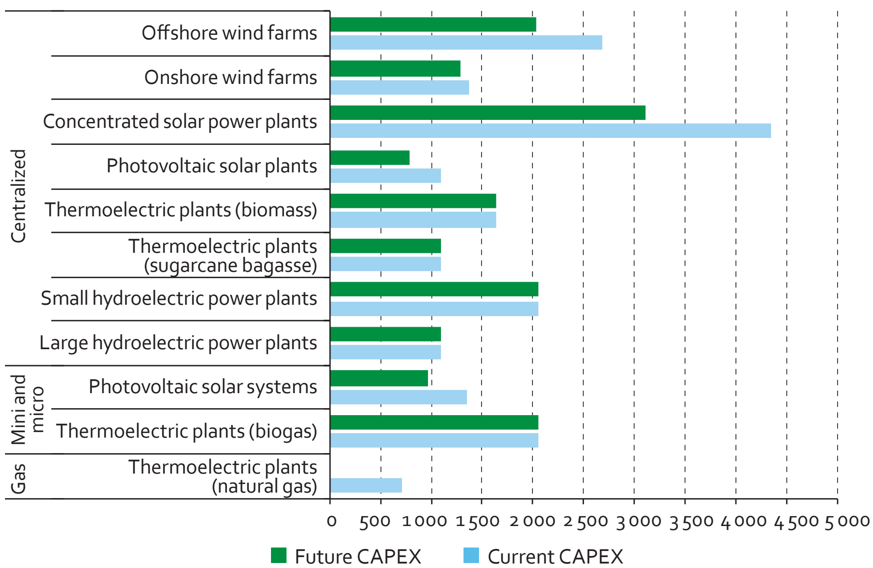
2. Technical-economic pillar

Power generation

The technology readiness level (TRL) for power generation was based on internal exchanges with the International Energy Agency (IEA), which carries out a survey at global level (IEA, 2019b). All power generation technologies considered here, both centralized and distributed, are classified as TRL 9.

Data on current capital costs (most recent data available) and future estimates (2025-2030) for electricity generation are presented here, as cost reductions are expected in the short term for some technologies. For the sake of comparison, investment costs for natural gas thermoelectric plants are also shown. Currently, this source has a lower CAPEX than any other. In the near future, only solar photovoltaic power plants would be competitive with natural gas thermoelectric plants, in terms of capital costs.

Figure III.9
CAPEX for power generation technologies
(In US$/kW)

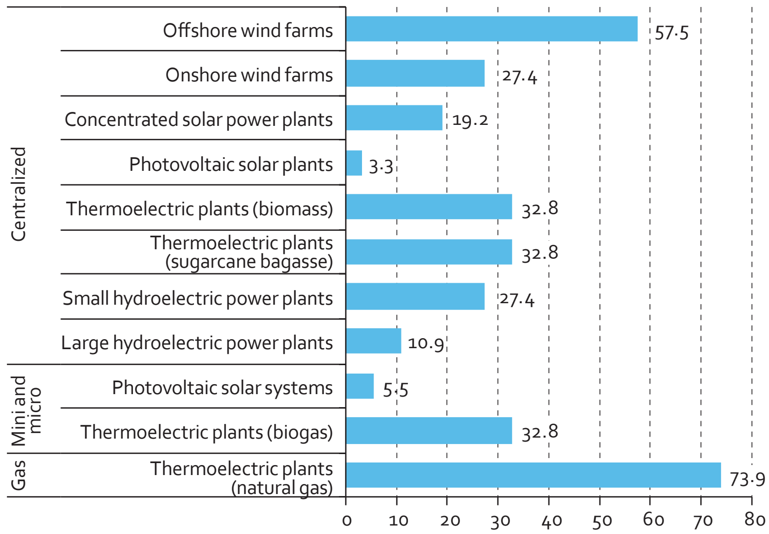


Source: Created by the authors based on Energy Research Office (EPE), *Estudos Para a Expansão da Geração – Custo Marginal de Expansão do Setor Elétrico Brasileiro Metodologia e Cálculo – 2017*, Brasília, Ministério de Minas e Energia/Empresa de Pesquisa Energética (MME/EPE), 2017; and Energy Research Office (EPE), *Nota Técnica PR 07/18 – Premissas e Custos da Oferta de Energia Elétrica no Horizonte 2050*, Rio de Janeiro, Ministério de Minas e Energia/Empresa de Pesquisa Energética (MME/EPE), November 2017.

For comparison purposes, the operating and maintenance costs for natural gas thermoelectric plants are also indicated, together with the OPEX for other power generation technologies. In this case, it is noteworthy that the OPEX for natural gas thermoelectric plants is significantly higher than that of any other source of electricity, mainly due to fuel costs.

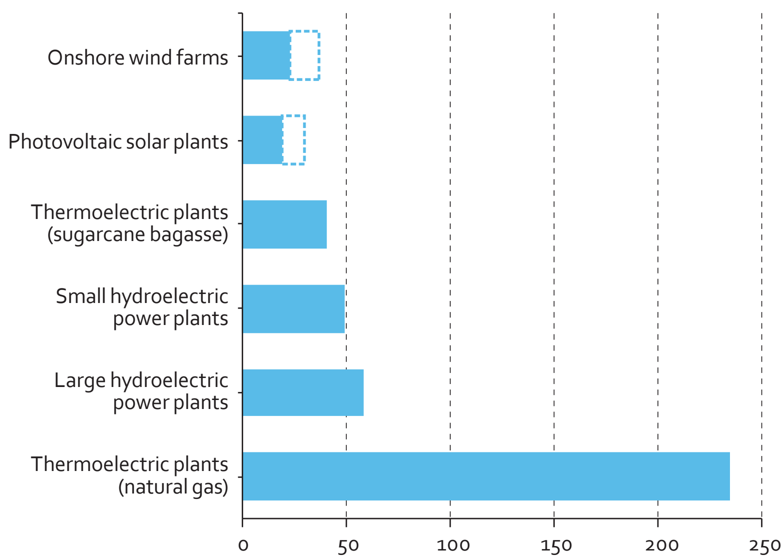
The total costs for centralized power generation technologies are presented as levelized cost of energy (LCOE). The margin shown for wind and solar photovoltaic power plants derives from regional cost variations within the country, being lower in the Northeast, and higher in the South. For the sake of comparison, the total costs of natural gas-fired power plants are also shown, which are much higher than those of all other sources analysed.

Figure III.10
OPEX for power generation technologies
(In US$/kW/year)



Source: Created by the authors based on Energy Research Office (EPE), *Nota Técnica PR 07/18 – Premissas e Custos da Oferta de Energia Elétrica no Horizonte 2050*, Rio de Janeiro, Ministério de Minas e Energia/Empresa de Pesquisa Energética (MME/EPE), November 2018.

Figure III.11
LCOE for centralized power generation technologies
(In US$/MWh)



Source: Created by the authors based on PSR, *Custos e Benefícios das Fontes de Geração Elétrica: Caderno de Geração*, Instituto Escolhas, August 2018.
Note: The margin shown for wind and solar photovoltaic power plants derives from regional cost variations within the country, being lower in the Northeast, and higher in the South.

Transport

The technological readiness level for transport technologies has also been based on internal exchanges with the IEA.

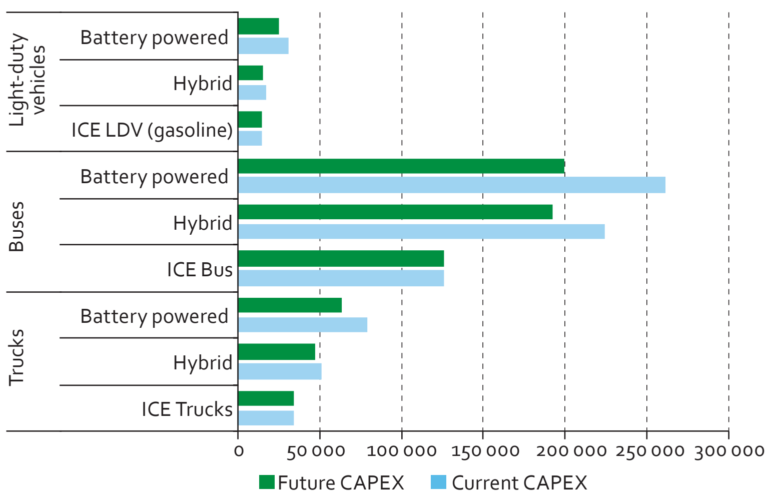
Table III.1
TRL for transport technologies

Low-carbon transport systems	TRL
Hybrid light-duty vehicle	9
Battery electric light-duty vehicle	9
Flex-fuel light-duty vehicle	9
Hybrid bus	9
Battery electric bus	8
Hybrid truck	8
Battery electric truck	8

Source: Created by the authors based on internal exchanges with the IEA.

For transport technologies, current cost data (most recent data available) and future estimates (2025-2030) are presented. For comparison purposes, CAPEX values for conventional ICE vehicles are also shown. The CAPEX for these vehicles is currently lower than that of any of the alternative technologies assessed. However, cost reductions are expected for all low-carbon technologies, especially those currently classified as TRL 8.

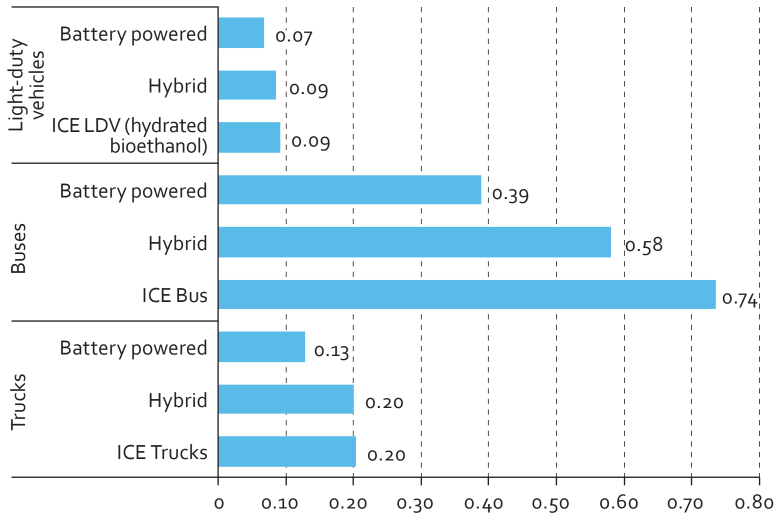
Figure III.12
CAPEX for transport technologies
(In US$ thousand/vehicle)



Source: Created by the authors based on C40, *Low-carbon technologies can transform Latin America's bus fleets*, C40 Cities, Climate Leadership Group, Clinton Foundation, Inter-American Development Bank, July 2013; Delft, *Zero emissions trucks: An overview of state-of-the-art technologies and their potential*, Stuttgart, July 2013; Docklands Light Railway (DLR*), Project Report: Alternative Transport Technologies for Megacities*, German Aerospace Center, Institute of Vehicle Concept, Stuttgart, February 2015; Greenpeace, *Dossiê Ônibus Limpo: Benefícios de uma transição para combustíveis renováveis na frota de São Paulo*, São Paulo, August 2016; International Council on Clean Transportation (ICCT), *PROMOBE: Avaliação Internacional de Políticas Públicas para Eletromobilidade em Frotas Urbanas*, Brasília, Agência Alemã de Cooperação Internacional/Ministério da Indústria, Comércio Exterior e Serviços (GIZ/MDIC), November 2019; and Union of Concerned Scientists (UCS), "Electric Vehicle Batteries: Materials, Cost, Lifespan "[online] https://www.ucsusa.org/resources/ev-batteries, 2018.

In terms of operating and maintenance costs, the situation is reversed, being higher for conventional ICE vehicles compared to those using low-carbon technologies. This is due to higher fuel costs and also higher maintenance requirements for ICE vehicles when compared to BEV, for example, which have fewer components than ICE vehicles.

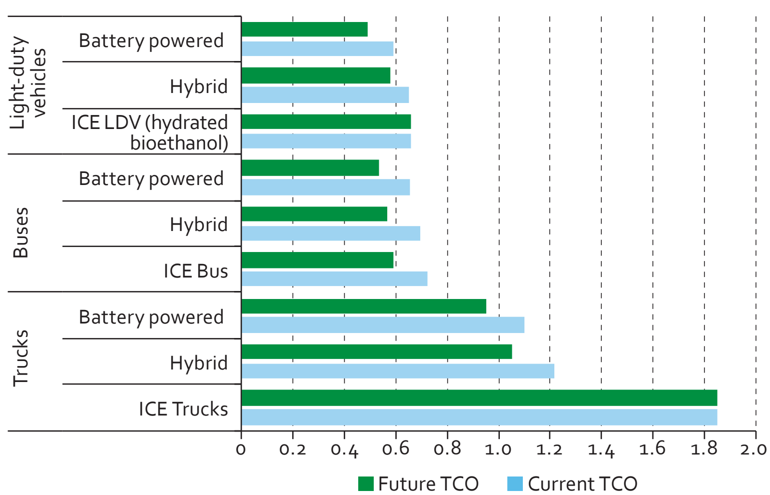
Figure III.13
OPEX for transport technologies
(In US$/km)



Source: Created by the authors based on International Council on Clean Transportation (ICCT), *PROMOBE: Avaliação Internacional de Políticas Públicas para Eletromobilidade em Frotas Urbanas*, Brasília, Agência Alemã de Cooperação Internacional/Ministério da Indústria, Comércio Exterior e Serviços (GIZ/MDIC), November 2019; Union of Concerned Scientists (UCS) (2018), "Electric Vehicle Batteries: Materials, Cost, Lifespan "[online] https://www.ucsusa.org/resources/ev-batteries, 2018; and International Energy Agency (IEA), *World Energy Outlook 2018*, IEA, Paris, 2018.

The total cost of ownership (TCO) for transport technologies is currently lower for hybrid and electric vehicles, mainly because their OPEX is lower, as shown earlier. In addition, some reductions are still expected.

Figure III.14
TCO for transport technologies
(In US$/km)



Source: Created by the authors based on International Council on Clean Transportation (ICCT), *PROMOBE: Avaliação Internacional de Políticas Públicas para Eletromobilidade em Frotas Urbanas*, Brasília, Agência Alemã de Cooperação Internacional/Ministério da Indústria, Comércio Exterior e Serviços (GIZ/MDIC), November 2019; Hagman, Jeans et al. (2016), "Total cost of ownership and its potential implications for battery electric vehicle diffusion", *Research in Transportation Business & Management*, vol. 18, March 2016; Lajunen, Antti and Timothy Lipman, "Lifecycle cost assessment and carbon dioxide emissions of diesel, natural gas, hybrid electric, fuel cell hybrid and electric transit buses", *Energy*, vol. 106; and International Energy Agency (IEA), *IEA G20 Hydrogen report: Assumptions*, Paris, 2019.

Biofuels

The TRL for biofuels was once again established on the basis of internal exchanges with the IEA.

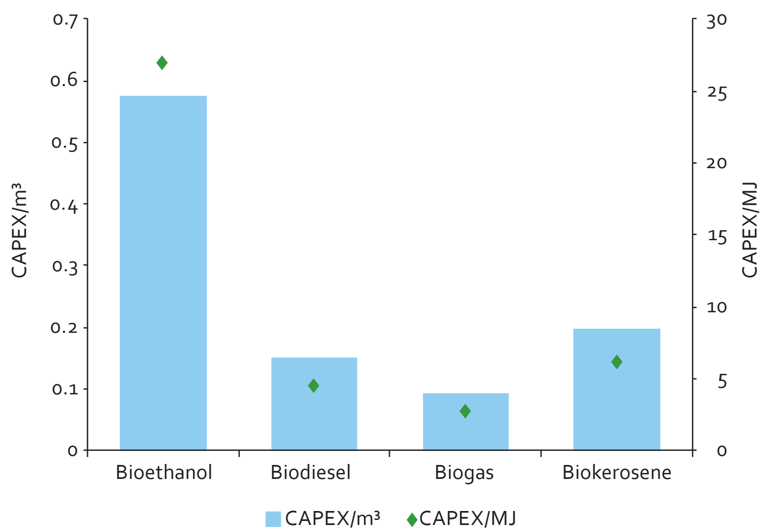
Table III.2
TRL for biofuel technologies

Biofuel technologies	TRL
Bioethanol	9
Biodiesel	9
Biogas	9
Biokerosene	8

Source: Created by the authors based on internal exchanges with the IEA.

No estimate was made on the evolution of future biofuel costs due to the lack of available data, but reductions should occur in all cases due to technological progress and learning curves.

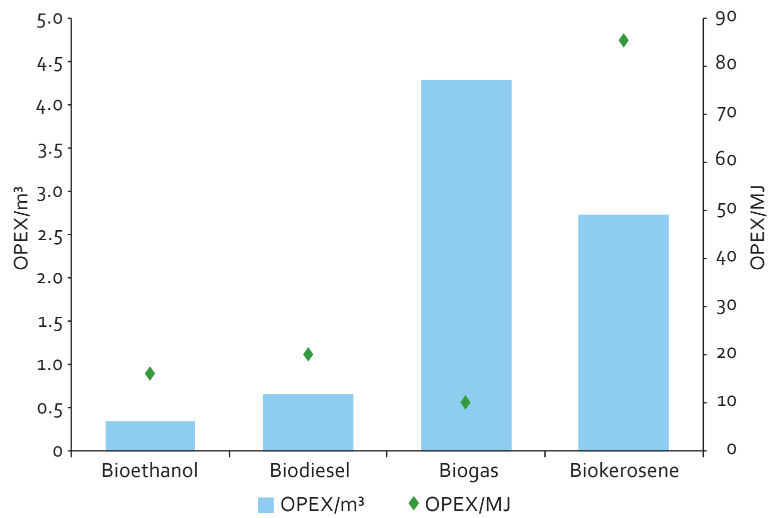
Figure III.15
CAPEX for biofuel technologies
(In US$/m³ and US$/MJ)



Source: Created by the authors based on Carvalho, Francielle, "Evaluation of the Brazilian Potential for Producing Aviation Biofuels through Consolidated Routes", *Master's thesis*, Graduate Programme in Energy Planning, COPPE, Universidade Federal do Rio de Janeiro, February 2017; Régis Rathmann (org.), *Modelagem integrada e impactos econômicos de opções setoriais de baixo carbono*, Ministério da Ciência, Tecnologia e Inovações (MCTI), ONU Meio Ambiente, Brasília, 2017; and Energy Research Office (EPE), *Nota Técnica EPE 019/2018 – Estudo sobre a Economicidade do Aproveitamento dos Resíduos Sólidos Urbanos em Aterro para Produção de Biometano*, Rio de Janeiro, Ministério de Minas e Energia/Empresa de Pesquisa Energética (MME/EPE), August 2018.

The reduced OPEX values for bioethanol, biodiesel and biogas are due to the aforementioned fact that the inputs for these biofuels are by-products of other agro-industrial processes (for example, sugar, soy protein and agricultural residues).

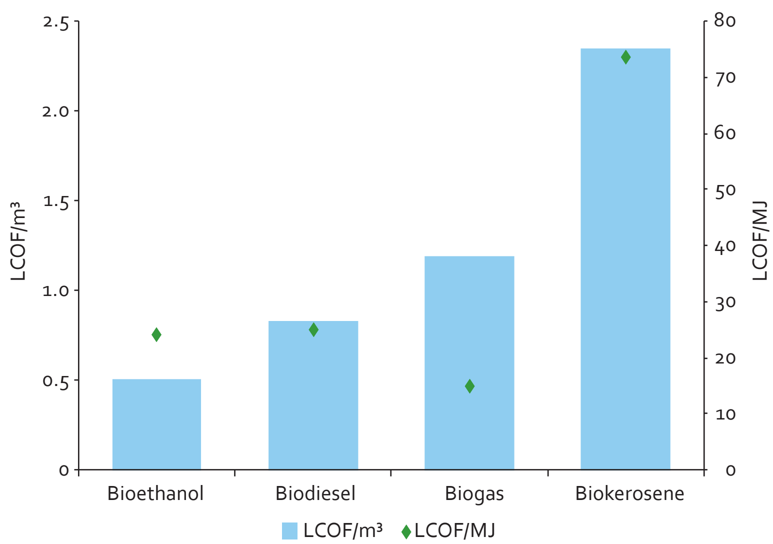
Figure III.16
OPEX for biofuel technologies
(In US$/m³ and US$/MJ)



Source: Created by the authors based on Carvalho, Francielle, "Evaluation of the Brazilian Potential for Producing Aviation Biofuels through Consolidated Routes", *Master's thesis*, Graduate Programme in Energy Planning, COPPE, Universidade Federal do Rio de Janeiro, February 2017; Régis Rathmann (org.), *Modelagem integrada e impactos econômicos de opções setoriais de baixo carbono*, Ministério da Ciência, Tecnologia e Inovações (MCTI), ONU Meio Ambiente, Brasília, 2017; and Energy Research Office (EPE), *Nota Técnica EPE 019/2018 – Estudo sobre a Economicidade do Aproveitamento dos Resíduos Sólidos Urbanos em Aterro para Produção de Biometano*, Rio de Janeiro, Ministério de Minas e Energia/Empresa de Pesquisa Energética (MME/EPE), August 2018.

Total costs for biofuels are presented in terms of the levelized cost of fuel (LCOF).

Figure III.17
LCOF for biofuel technologies
(In US$/m³ and US$/MJ)



Source: Created by the authors based on Carvalho, Francielle, "Evaluation of the Brazilian Potential for Producing Aviation Biofuels through Consolidated Routes", *Master's thesis*, Graduate Programme in Energy Planning, COPPE, Universidade Federal do Rio de Janeiro, February 2017; Régis Rathmann (org.), *Modelagem integrada e impactos econômicos de opções setoriais de baixo carbono*, Ministério da Ciência, Tecnologia e Inovações (MCTI), ONU Meio Ambiente, Brasília, 2017; and Energy Research Office (EPE), *Nota Técnica EPE 019/2018 – Estudo sobre a Economicidade do Aproveitamento dos Resíduos Sólidos Urbanos em Aterro para Produção de Biometano*, Rio de Janeiro, Ministério de Minas e Energia/Empresa de Pesquisa Energética (MME/EPE), August 2018.

Biofuels have an important additional role for the diversification of energy supply sources, as can be seen from the percentage share of biofuels in the energy mix of transport fuels in Brazil.

Table III.3
Contribution of biofuels to energy diversification
(Percentages)

Biofuel	Share in the 2018 transport energy mix
Bioethanol	28.1%
Biodiesel	11.5%
Biogas	n.d.
Biokerosene	n.a.

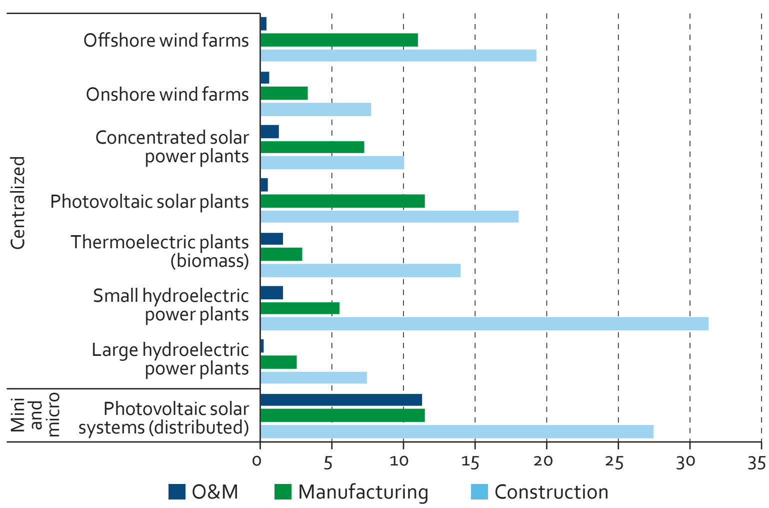
Source: Created by the authors based on Energy Research Office (EPE), *Balanço Energético Nacional 2018: Relatório síntese, ano base 2017*, Brasília, Ministério de Minas e Energia/Empresa de Pesquisa Energética (MME/EPE), 2018.

3. Social pillar

Power generation

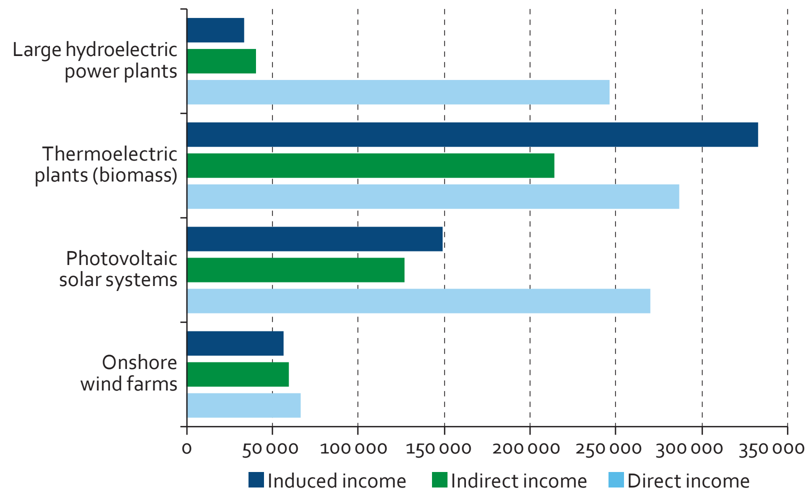
In power generation, jobs are computed for the construction, manufacturing and operation phases. In the sugar and alcohol sector, cogeneration units do not add a significant amount of direct jobs, since this activity is also linked to the production of sugar and bioethanol. Distributed generation solar photovoltaic systems are a great source of jobs, especially in O&M, due to their geographically diffuse nature.

Figure III.18
Job creation for power generation technologies
(In jobs/MJ and jobs/MJ/year)



Source: Created by the authors based on Greenpeace, *Revolução Energética – Rumo a um Brasil com 100% de energias limpas e renováveis*, Rio de Janeiro, 2016; IEA (International Energy Agency), *World Energy Investment*, Paris, 2017; Energy Research Office (EPE), *Nota Técnica EPE 026/2018 – Análise socioambiental das fontes energéticas do PDE 2027*, Rio de Janeiro, Ministério de Minas e Energia/Empresa de Pesquisa Energética (MME/EPE), November 2018; and International Renewable Energy Agency (IRENA), *Renewable Energy and Jobs: Annual Review 2019*, United Arab Emirates, June 2019.

Figure III.19
Income generation for centralized power generation technologies
(In US$ thousand/year)



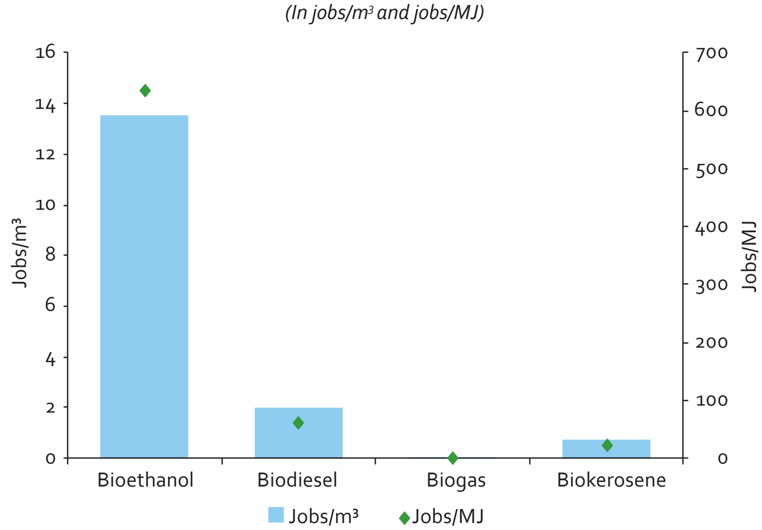
Source: Created by the authors based on São Paulo State Environmental Agency (CETESB), "Emissões Veiculares no Estado São Paulo–Fator de Emissão 2018" [online], https://cetesb.sp.gov.br/ veicular/relatorios-e-publicacoes/, 2019.

Income generation —whether direct, indirect or induced— was taken into account for four power generation technologies, based on data availability: large hydroelectric power plants, solar photovoltaic plants, forest biomass thermoelectric plants and onshore wind farms.

Biofuels

Job creation in the biofuels sector, according to REN21 (2019), includes the aggregated agricultural and industrial processing phases for bioethanol, but this is not explicit in the case of biodiesel. Therefore, one may wonder whether this might explain the significant difference in the number of jobs created for these two types of fuel. However, it is known that soy is not a very labour-intensive crop. In the case of biogas, job creation is not significant because most of the activity is associated with landfills.

Figure III.20
Job creation for biofuel technologies
(In jobs/m³ and jobs/MJ)



Source: Created by the authors based on National Agency for Petroleum, Natural Gas and Biofuels (ANP), "RenovaCalc 2019" [online], www.anp.gov.br › images › Consultas_publicas › CP10-2018_Calculadora, 2019; REN21, *Renewables 2019–Global Status Report*, Paris, 2019; and Wei, Max, Shana Patadia and Daniel Kammen, "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?", *Energy Policy*, vol. 38, ed. 2, February 2010.

C. Improvement opportunities and recommendations

This chapter provides a set of performance indicators for selected low-carbon energy solutions in Brazil, as well as their estimates. The assessment considers different dimensions of sustainable development, including indicators from the environmental, technical-economic, social and political-institutional pillars.

An important finding, which has been corroborated by inputs from the experts attending the EBP Workshop in October 2019, reveals that no technology family is a silver bullet, i.e. no single family meets the requirements of all sustainability pillars. This finding highlights one of the key aspects of the Big Push for Sustainability: there are clear advantages to working with a combination of complementary investments (instead of betting on a single technology) when seeking to achieve benefits in multiple sustainable development dimensions. Another finding is that no single indicator can offer a "one size fits all" solution, and some of them only allow qualitative analysis. In addition, potential interconnections between indicators should be considered. The isolated analysis of an indicator may lead to misinterpretation. Different indicators are usually complementary, and a cross-sectional assessment is required to achieve a comprehensive understanding of the issue. Furthermore, not every indicator is applicable to all technologies.

On the other hand, the data used in this study come from different sources, which apply different methodologies and assumptions. This should be taken into account when interpreting the results. In this study, the results were validated by a team of experts during the aforementioned EBP Workshop, held at the CGEE in Brasília on 30 and 31 October 2019, in line with the actions set for the EBP project, as described in the Introduction.

Some other aspects (not usually captured by the set of indicators considered in the present study) are nonetheless relevant to the design of policies and strategies. These include intermittency and reliability of energy sources, co-benefits, potential pressure on land use, capacity for implementing technologies, innovation metrics, as well as time and space scales. In addition, taking into account all stages of energy production and use could further improve these indicators. A life-cycle assessment that considers the agricultural phase (if applicable), the supply chain and the disposal/decommissioning stage would be able to cover aspects that are more relevant to decision-making.

The relevance of the selected indicators is another aspect raised by the experts. Indicator relevance may vary according to which decision-making process they refer to. Methods such as multi-criteria analysis and Delphi questionnaires for qualitative assessments can be important tools for setting weights and priorities. In addition, the present analysis did not contemplate power transmission, distribution and storage technologies, as there is little data available on them. The impact of smart grids, for example, is quite diffuse and therefore difficult to assess, albeit relevant.

Considering the aspects above, one of the main priorities for future action is strengthening efforts toward identifying gaps in existing databases. This will improve the ability to quantify indicators and harmonize methodologies. Working with more cohesive data sources is essential to ensure that technologies are fully comparable. A more accurate diagnosis would make it possible to identify other institutions in charge of providing this type of data regularly, and thus monitor the progress of different technological solutions more closely. In this regard, it would be convenient to increase the number of institutions engaged in this process and that can contribute to it. Finally, it is important to identify mechanisms that are capable of guaranteeing the continuity of the development, updating, scope and adoption of indicators.

A well-designed set of indicators can be of great use to assist in decision-making, providing technical information on multiple dimensions of sustainable development. A well-informed decision-making process leads to better-quality and well-coordinated investments in research and development, and to the adoption of adequate mechanisms to encourage innovation, thus contributing to a big push forward in the energy sector in Brazil.

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IV. Incentive mechanisms for energy innovation in Brazil

A. Background

The third axis of the Energy Big Push (EBP) project refers to the identification of strategic guidelines and priority instruments to drive innovation investments in the area of low-carbon energy in Brazil. This chapter is based on the final report on Axis 3 of the EBP, entitled "Incentive mechanisms for clean energy innovation in Brazil: Paths for an energy big push", which is available for further details and additional information. The main objective of this axis was to develop strategic guidelines and propose mechanisms to encourage innovation investments in clean energy and energy efficiency. With a view to contribute to an energy big push in Brazil, the activities under Axis 3 of the EBP included, among others: a survey and analysis of the existing incentive mechanisms driving Brazilian energy innovation; a review of selected international experiences based on IEA country reports and other official sources; and recommendations on strategic guidelines and priority instruments to accelerate innovation in clean and sustainable energies in Brazil, including a set of 16 lines of action.

B. Survey and analysis of existing incentive mechanisms for energy innovation in Brazil

The survey and analysis of the existing incentive mechanisms for energy innovation in Brazil was the first step in the work, and consisted of a mapping exercise of incentive mechanisms and instruments that directly or indirectly contribute to promoting energy research, development and innovation (RD&I) in the country. Given that energy innovation takes place in a broad, complex environment of innovation processes, this exercise required the inclusion of non-energy specific instruments that foster innovation in general, that is, instruments that can apply but are not limited to the energy sector. Examples include science grants, research infrastructure and programmes (e.g. grants and calls for projects), funding for collaborative research projects, funding to support scientific events, economic subsidies, subsidized credit lines (interest equalization schemes), variable income investments, tax incentives for innovation and other types of incentives. Specific mechanisms to promote innovation in the energy sector were also identified, including the Electric Energy Sector Fund, the Electric Energy Sector Research and Technology Development Programme, the Land and Water Transport Sector Fund, and Route 2030 —Mobility and Logistics (*Rota 2030*). In addition to R&D incentive mechanisms, this mapping exercise covered incentive mechanisms for innovation during the deployment and commercial stages. The final technical report for Axis 3 is available for additional details on these instruments.

These incentive mechanisms that contribute to supporting clean energy technological development were then classified into four core functions of innovation systems, based on a framework of innovation systems developed by the IEA (2019b and 2020b):

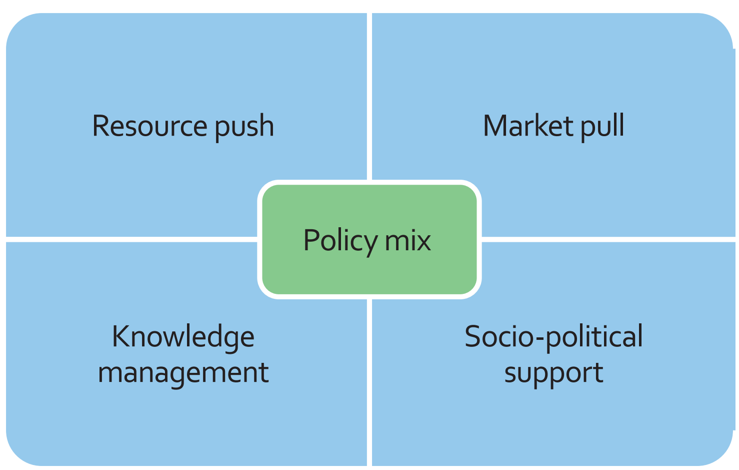
(i) Resource push: policies and incentive mechanisms that provide resources, or inputs, to the energy innovation system, thereby pushing product and process development along the innovation value chain. Key inputs include: the provision of funds for energy R&D, skilled workforce, the availability of research infrastructure, clearly defined research priorities to guide innovation activities etc.;

(ii) Knowledge management: policies and incentive mechanisms that foster knowledge creation in fields relevant to the energy sector, as well as its effective dissemination and transmission among innovation stakeholders (e.g. academia, technology experts, advocacy groups, industry players, citizens etc.) and along the value chain of innovation from a technology development stage to the next;

(iii) Market pull: policies and incentive mechanisms that encourage innovation by promoting the creation of markets for and the application of new technologies, thereby pulling product and process development through the innovation value chain. Policy tools include, for example, public procurement for emerging technologies, setting market incentives (e.g. quotas, standards, carbon pricing), ensuring healthy access to finance for energy entrepreneurs, facilitating demonstration, etc.; and

(iv) Socio-political support: policies and incentive mechanisms that promote the engagement of all relevant stakeholders for technological change, seeking to achieve buy-in from citizens, consumers and industry players.

Diagram IV.1
Four core components of successful energy innovation systems



Source: Created by the authors based on International Energy Agency (IEA), "ETP Special Report on Clean Energy Innovation" [online] https://www.iea.org/reports/clean-energy-innovation, July 2020; and International Energy Agency (IEA), "Clean energy transitions: Accelerating innovation beyond 2020" [online] https://www.iea.org/reports/clean-energy-transitions-accelerating-innovation-beyond-2020 [Accessed on 4 October 2019], 2019.

Table IV.1 presents an overview of existing incentive mechanisms for energy innovation in Brazil, and although this is a simplification, each has been allocated to one of the four pillars of the IEA energy innovation framework described above.

Table IV.1
Selection of mechanisms to encourage energy innovation in Brazil, by function of energy innovation systems

Providing resources (Resource push)	Generating knowledge (Knowledge management)	Supporting markets (Market pull)	Promoting socio-political support (Socio-political support)
Science scholarships	Science scholarships	Wind, solar, biomass: Market creation (auctions in the electricity sector, discount on energy tariffs, net metering, tax incentives) Wind and solar: Deployment (interest equalization schemes, Special Incentive Scheme for Infrastructure Development – REIDI, local content requirements, tax incentives)	Energy efficiency: Energy Efficiency Law, PROCEL, CONPET-Petrobras, PBE-Inmetro
Cooperation projects (FINEP CONECTA, BNDES FUNTEC, EMBRAPII)	Research support (research projects and infrastructure)	Electric mobility: Market creation (tax incentives through Route 2030, IPVA, II and IPI) Deployment (subsidized loans)	Biofuels: PBE-MME, RENOVABIO Wind and solar: net metering
Economic subsidies, Spark Programme *(Programa Centelha)*, TECNOVA	Cooperation projects (Green & Yellow Fund, state funds via FAPs, FINEP CONECTA, BNDES FUNTEC, EMBRAPII)	Energy efficiency: Deployment (PEE ANEEL, subsidized loans, Route 2030)	
Variable income investment (FINEP and BNDES funds and programmes)	International cooperation (FINEP grant)	Biofuels: Market creation (mandatory blending, biodiesel auctions, RENOVABIO) Deployment (PBE-MME, subsidized loans)	
Subsidized loans (FINEP and BNDES programmes)	Sectoral funds (agribusiness, biotechnology, land and water transport, energy)		
Tax incentives (Goodness Law [*Lei do Bem*], IT Law [*Lei da Informática*], Route 2030, PADIS)			
ANEEL R&D			
Sectoral funds (agribusiness, biotechnology, land and water transport, energy)			

Source: Created by the authors.

The analysis carried out during this first stage allowed to conclude that, despite the existence of multiple mechanisms, in addition to sectoral policies and plans that address clean energy in the fields of energy, transport and climate, Brazil does not have a coordinated and long-term national strategy for low-carbon energy innovation. In addition, the following main obstacles have been identified, and policy discussions should identify ways to overcome some of these pressing challenges in order to further develop these technologies in Brazil:

(i) Ensuring the sustained availability and avoiding volatility of public funds for energy R&D activities overtime, as well as the alignment of funding for R&D with national priorities, to strengthen the durability, credibility and effectiveness of resource-push mechanisms;

(ii) Developing consistent plans and links between energy, climate and national development priorities, including energy access, security and sovereignty, renewable energy development, energy efficiency improvement, carbon capture, utilization and storage, productivity and competitiveness, etc.;

(iii) Enhancing priority setting mechanisms so as to better coordinate energy, climate, science, technology & innovation (ST&I), and development priorities with incentive mechanisms;

(iv) Strengthening coordination among different government agencies and innovation stakeholders (e.g. academia, technology experts, advocacy groups, industry players, citizens) with regard to priority setting;

(v) Putting forward balanced policy packages to support energy innovation, such as a combination of targeted and aligned resource-push and market-pull policies, rather than isolated strategies —several mechanisms with an explicit focus on the energy sector are concentrated in these areas, as per table IV.1;

(vi) Strengthening support for innovative processes at all stages, including from early basic research through experimental development and early commercialization in niche markets. Innovation is a learning process that is intrinsically subject to risk —which is associated with predictable events— and uncertainty —related to unknown and uncertain events whose probability is incalculable— at various degrees. Basic research, for instance, involves extremely high uncertainty and risk levels, whereas secondary technical improvements to a known product are less subject to them. It is important to note that innovations involving higher the degrees of uncertainty and risk require more robust incentive mechanisms (Gordon and Cassiolato, 2019). For example, disruptive innovation projects, such as those that involve radical product and process innovation, require powerful incentives that effectively reduce uncertainty and risk such that investments in them become attractive, which can include non-reimbursable finance, risk capital and pre-commercial procurement (see table IV.2).

Table IV.2
Links between type of innovation, uncertainty, risk and a selection of incentive mechanisms

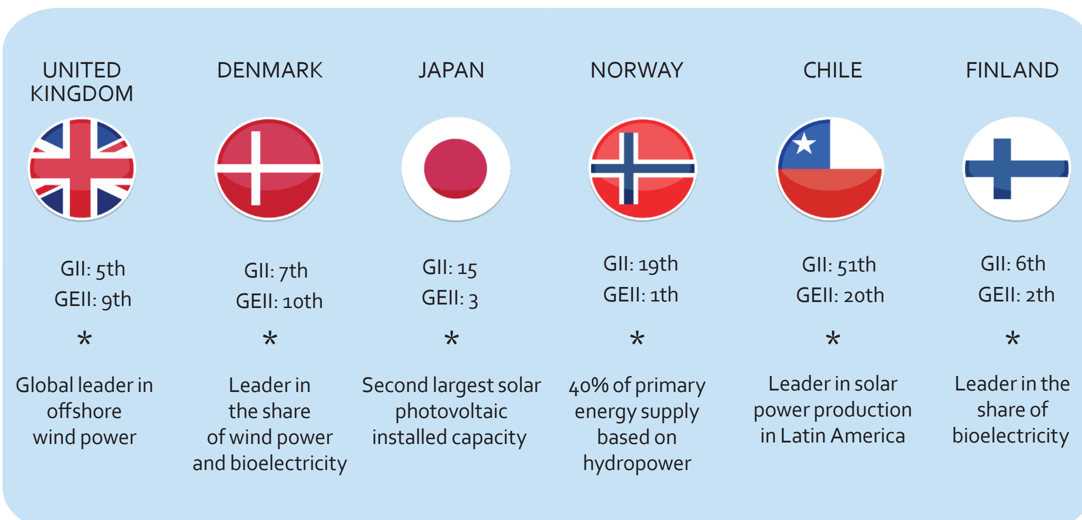
Type of innovation	Uncertainty	Risk	Incentive mechanisms
Basic research and invention	Strong/True	Incalculable	Non-reimbursable finance Pre-commercial procurement Risk capital
Radical product and process innovation developed outside the firm	Extremely high	Very high	Public shareholding Economic subvention (grant) Non-reimbursable finance Public procurement Risk capital
In-company product and process innovation	Very high	High	Non-reimbursable finance for joint firm and science, technology and innovation (STI) centres projects Public shareholding Economic subvention (grant) Non-reimbursable finance Public procurement Risk capital
New generation of well-known products	Moderate	Moderate	Subsidized loans (e.g. interest equalization schemes) Non-reimbursable finance for joint firm and STI centres projects
Innovation under licensing; product differentiation; product and process improvement and adaptation	Low	Low	Reimbursable finance (which can be subsidized in some cases) Fiscal incentive
Product differentiation, innovation of a known product, late uptake of process innovation within own firm, secondary technical improvements	Very low	Very low	Reimbursable finance (e.g. loans) Fiscal incentive

Source: Created by the authors based on José Luis Gordon and José Eduardo Cassiolato, "O Papel do Estado na Política de Inovação a partir dos seus instrumentos: uma análise do Plano Inova Empresa", *Revista de Economia Contemporânea*, vol. 23, no. 3, Rio de Janeiro, November 2019.

C. Review of international experience

The survey and analysis of incentive mechanisms in Brazil helped to identify gaps and obstacles to energy innovation in the country. This served as an input for the next step: a review of international experiences. We sought to analyse lessons learned and practices implemented in other countries to address similar issues, and which might be useful for the case of Brazil. The selection of international experiences targeted countries that: have a prominent position in general innovation and renewable energy innovation rankings; have started or completed a relevant low-carbon energy transition process; have a coherent set of objectives, policies and incentives for the development of clean energy innovation; have such objectives, policies and incentives reflected in governance mechanisms meant to coordinate activities of different stakeholders within a coherent priority-setting process (notably consistency between energy, climate, and science, technology & innovation plans and policies); may present R&D incentive mechanisms in line with their national clean energy innovation priorities; and have some similarity with Brazil in terms of energy priorities. The six countries selected for this review of international experiences were: the United Kingdom, Denmark, Japan, Norway, Chile and Finland (see diagram IV.2).

Diagram IV.2
Countries selected for the international experience review



Source: Created by the authors based on Cunliff, Colin and David Hart, "Global Energy Innovation Index: national contributions to the global clean energy innovation system", *Information Technology and Innovations Foundation*, August 2019; Cornell University, Institut Européen d'Administration des Affaires (INSEAD) and World Intellectual Property Organization (WIPO), *The Global Innovation Index 2019: Creating Healthy Lives—The Future of Medical Innovation*, Ithaca, Fontainebleau and Geneva, 2019; and International Energy Agency (IEA), *World Energy Outlook 2019*, IEA, Paris, 2019.
Note: GII refers to the Global Innovation Index, and GEII refers to the Global Energy Innovation Index.

The review of international experience helped to identify important practices and lessons learned that may be useful to Brazil.

Long-term strategies, objectives and plans to guide incentive mechanisms

Incentive mechanisms are means to ends. Policy objectives are part of broader plans connected to a country's long-term strategy and vision for the future, including the future of energy systems and the long-term sustainability of development. Before they can be translated into public policies, long-term strategies, objectives and plans require coordination and the engagement of all levels of government in decision-making processes, as well as other relevant innovation stakeholders. In Denmark, for example, energy and climate policies were designed together by many stakeholders, and the Digital Strategy involved three levels of government: national, regional and municipal. Broad consultation and social participation are vital to identifying common national aspirations, building consensus, trust and legitimacy, increasing transparency, managing risks, and generating the necessary engagement for transformative change. In Chile, the development of their 2050 National Energy Policy incorporated a democratic spirit, establishing three complementary instances of engagement: at the political-strategic, technical and public levels. Participatory decision-making processes can help to design coordinated energy and climate policies, consider new perspectives and ideas, and establish long-term goals and policies that are more resilient and less subject to changes due to elective cycles and mandates.

Structured governance to coordinate and align the areas of climate, energy, and science, technology & innovation (ST&I)

Policy coordination is a major challenge for any country. The countries covered in this study chose different solutions for structuring their governance arrangements to coordinate and align energy and climate policies. In the United Kingdom, for example, both policies are under the responsibility of a single government department (equivalent to a ministry in Brazil): the Department for Business, Energy and Industrial Strategy (BEIS). In Japan, a long-term strategy has been established tying energy and climate goals under the same framework. In Finland, a similar arrangement can be found in the 2030 National Energy and Climate Strategy. The reviewed countries have diverse governance arrangements in place, but they all establish clearly shared responsibilities and roles in a way that allows coordination and alignment across policy areas.

Cross-cutting communication and multi-stakeholder coordination

The review of international experience has identified a common feature in all leading countries: key government agencies, decision makers and stakeholders in the areas of climate, energy, and science, technology & innovation are engaged in cross-cutting communication and multi-stakeholder coordination initiatives. In these countries, relevant stakeholders have been mobilized for the design, implementation and evaluation of policies in these areas. Different arrangements can be put in place to manage coordination efforts across different areas. Finland, for example, has enshrined coordination rules in its legislation. The Climate Change Act (609/2015) defines each actor's responsibilities and assigns the overall coordinating role to the Ministry of Economy's Energy Department. Coordination is a challenge not only for different government departments and agencies. It also requires further interactions between public entities, private companies, science and technology institutions (STIs), and civil society. In the UK, for example, government-supported R&D centres coordinate their efforts with industry actors and STIs for the promotion of innovation projects. Norway's R&D programmes and institutions (OG21, ENERGY21) include board members from different segments of society.

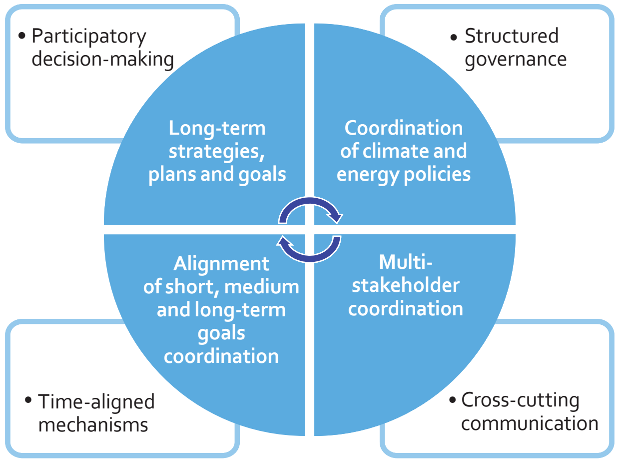
Time-aligning R&D incentive mechanisms and energy and climate priorities

Energy, climate, and science, technology & innovation are long-term policy areas, a factor which underlines the importance of aligning goals over time. Japan provides an example of the importance of time alignment. The country first established medium- and long-term political goals, and thereafter focused on short- and medium-term incentives to achieve these long-term goals. Consistency among different R&D mechanisms over time is needed, according to each country's priorities.

Balance between different incentive mechanisms

The review of international experience illustrates that a balanced set of policy mechanisms to encourage innovation across all four key areas of the IEA energy innovation framework (see diagram IV.1) contributes to encouraging innovative technology development. Nearly all reviewed countries feature a balanced combination of incentives for innovation, notably between resource-push and market-pull levers. In addition, international experience highlights the importance of applying a wide range of instruments (among which mandatory ones), including targeted market-pull mechanisms that can contribute to creating niche markets in some instances, such as feed-in tariffs and renewable energy quotas for emerging energy technologies.

Diagram IV.3
Long-term goals and coordination within government, across stakeholders and over time



Source: Created by the authors.

Strong support at all stages of the innovation process

International experience also shows that supporting all stages of the technology innovation process (e.g. from basic and applied research to experimental development, demonstration and commercialization) is important to ensure new ideas that have the potential to accelerate low-carbon energy transitions actually reach markets. In Denmark, for example, different entities are in charge of different stages in the process. R&D funding agencies support basic research and part of the development stages; local energy agencies support experimental development and demonstration of new technologies; and innovation funds support the commercialization of technology through channels available to large corporations, small- and medium-sized enterprises (SMEs), startups and STIs. The analysis of international experience also suggests that the technological development and commercialization stages of energy innovations rely on robust and strong initiatives that support projects in cooperation with companies of all sizes —including public R&D centres, such as ORE Catapult (United Kingdom) or the National Institute of Advanced Industrial Science and Technology (Japan). Networking services and incubators also play an important role. This finding underlines the importance of applying different instruments according to the stage of the innovative process, as shown in table IV.2.

Focus on the transformation of energy systems as a whole

R&D programmes in the countries reviewed in this study focus on widely understood low-carbon energy transitions, which involve transforming an entire energy system, rather than just promoting some specific energy sources. In addition to renewable energies, complementary areas are also seen as priorities for ensuring a deep transformation of an energy system, such as aspects that relate to system's integration of renewables (distributed energy generation, energy storage, electric mobility and charging infrastructure, energy efficiency and demand side management). Finland's Smart Energy and the UK's Energy System Catapult are examples of innovation programmes that seek to induce the incorporation of several technologies into the energy sector, in addition to renewable energy sources. These technologies, including digitalization, the internet of things (IoT), artificial intelligence, energy storage systems and smart grids, can improve an energy system's connectivity and integration levels, as well as optimize energy production and consumption from a systemic point of view (IEA, 2019c and 2017a). This broad focus also requires incentive mechanisms to build new business models and target consumer demand.

Strengthening the transformation of knowledge into technology and innovation

In Brazil, knowledge is generated mainly through scientific publications by academia: in 2016, Brazil ranked 13th worldwide in the volume of published scientific articles. Patent registrations by academic and research organizations in Brazil have increased since the early 2000s. However, there are limited links between research carried out in academia and its deployment or development by industry, government, or society. The review of international experience shows that leading countries have programmes focused on transforming research developed by academia into practical applications or solutions for businesses or governments, etc. (e.g. in public health systems). For example, Japan's ACCEL programme funds proofs of concept (PoC) to bridge the gaps and enable the practical application of the most relevant research outputs achieved by projects funded by basic research programmes. The country also sponsors the A-STEP programme, which seeks to bring innovations developed by academia into the market. The A-STEP programme funds the entire innovation chain. A key lesson that can be learned from reviewing international experience, including A-STEP, is that the specific incentive mechanism (grants or interest-free loans) to be employed should take into account the stage of technological development and innovation (theoretical or more advanced research). Thus, earlier stages (basic research, for example) require more robust incentives (such as economic grants, non-reimbursable funding, etc.), as the early stages of innovation are also those that involve higher risks and uncertainties. Other instruments, such as credit lines that apply interest rates closer to market rates, are more appropriate for the later stages of innovation (such as commercialization), in which technological readiness translates into lower risk and higher chances of profit.

Targeted market-pull levers such as public procurement for emerging technologies can be a strong incentive mechanism for energy innovation

In Finland, the KEINO Competence Centre is a network-based organization that brings together a number of public procurement and innovation support stakeholders. It is funded by the Ministry of Economic Affairs and Employment (MEAE), and focuses on developing skills for sustainable and innovative public procurement, as well as expanding good practices at all levels of government. Several strategies and plans, both at national, regional and organizational levels, have identified public procurement as a tool for achieving sustainability commitments. KEINO Centre's key objective for 2018-2021 is to increase the number of innovative and sustainable purchases by 5%. Finland's case illustrates how public procurement can be adapted to promote sustainable solutions. Generally, it is important to note that market-pull mechanisms (such as public procurement for emerging technologies) need to be well designed, targeted, and aligned with resource-push inputs to the innovation system (IEA, 2019a).

The role of international collaboration

International collaboration on energy innovation is increasingly relevant to achieving exponential cost reduction and accelerated growth in the deployment of clean energy solutions. Chile provides an iconic example of international cooperation. Its solar power programme (*Programa Energía Solar*) relies heavily on German cooperation. The programme aims to develop a national solar power industry with cutting-edge technological capabilities to deal with local challenges, and to make Chile a competitive participant in the global solar power market. Together with the Inter-American Development Bank (IDB), the German government, through its own development bank, is co-funding projects to install concentrated solar power plants (CSP) in Chile. In addition, a German innovation centre was established in Chile (Fraunhofer Chile Research), and won a bid to develop a centre of excellence in solar power technologies in 2012/2013. The particularities of the Chilean desert pose different challenges for solar power generation compared to Germany or other countries. Furthermore, the set of reviewed countries extensively take part in the Technology Collaboration Programme by IEA, a global network of over six thousand energy experts from fifty-five countries.

D. Relevance in the context of the Big Push for Sustainability

In many ways, the findings of EBP Axis 3 are directly in line with the Big Push for Sustainability approach. As discussed in Chapter I, national aspiration is the most important pillar in the Big Push for Sustainability, when it comes to steering transformative investments towards a more sustainable development style. There is no "one size fits all" sustainable development style, or an approach that applies equally to all countries, but there is a wide range of possible options. Understanding and capturing what each society envisions and desires in terms of its future development is, by far, the most important pillar, since it will guide the entire framework of policies, plans and measures to be implemented. This aspect stands out clearly in the work carried out under Axis 3, both in the review of international experience, and in the recommendations for an Energy Big Push in Brazil, as will be seen below.

The second guiding pillar in the Big Push for Sustainability approach is triple efficiency, which also stands out in the work carried out under Axis 3. Schumpeterian efficiency points out that a more integrated, complex and knowledge-intensive production matrix generates positive learning and innovation externalities that permeate the whole value chain. In other words, this is innovation efficiency, which is the EBP's core objective. In reviewing the international literature, the importance of investing in energy innovation becomes clear as part of a strategy not only for energy transition, but also for development. Keynesian efficiency, in turn, highlights the efficiency gains from specializing in the production of goods whose demand grows relatively more, generating multiplier effects and positive impacts on the economy and jobs. Keynesian efficiency is closely related to Schumpeterian efficiency, since the fastest growing markets tend to be those with the greatest technological and innovation dynamism. This finding was also observed in this study, since investments in clean energy innovation have allowed the reviewed countries to compete in rapidly expanding global energy markets, such as the variable renewable energy market (e.g. solar and wind power) or the electric mobility market. The sustainability efficiency, which stresses the classic tripod of economic viability, social justice and environmental sustainability, is evident in the analysis, which highlighted economic opportunity issues related to the emergence of new business models, the relevance of participatory decision-making mechanisms, and the guidance provided by climate commitments to reduce greenhouse gas emissions.

In addition to the clear link with the guiding pillars of the Big Push for Sustainability, coordination is another recurring aspect in the activities carried out under Axis 3, which is also central to this approach. A broad coordination between public and corporate, national and subnational, sectoral, fiscal, regulatory, financial and planning policies, among others, and different stakeholders around the guiding pillars of new development styles is the condition for attracting national and foreign investments, both public and private, as well as ensuring that energy innovation activities are aligned with long-term national priorities and policy goals. These can indeed give a big push towards a new virtuous circle of economic growth, job creation, income generation, reduction of inequalities and structural gaps, and promotion of environmental sustainability. As this document points out, only comprehensive and unrestricted coordination may leverage the large volume of investments that is required to launch the desired transformation processes.

Thus, there is a clear match between the findings of Axis 3 and the main conceptual elements of the Big Push for Sustainability, which reinforces its role as a guiding approach towards more sustainable development styles, including in the area of energy.

E. Action lines for an Energy Big Push in Brazil

The final recommendations result from a collaborative effort within the scope of EBP activities (working groups), which included the survey and analysis of mechanisms to encourage energy innovation in Brazil, the review of international experience, and the valuable inputs on the draft recommendations provided by experts during the workshop. The final recommendations for accelerating clean energy innovation in Brazil are structured around three different action levels:

1. Strategic Level

This level refers to high-level decisions regarding strategic areas for innovation in energy; climate change; and science, technology & innovation (ST&I) policies. Key government bodies and other relevant stakeholders should come together in an Energy Innovation Committee (EIC), or an equivalent forum created to coordinate all stakeholders in a priority-setting effort. Such EIC would define the strategic technology areas required for an Energy Big Push in Brazil (from energy production to distribution and use, including specific renewable sources of energy, such as wind, solar, biofuels, etc., smart distribution grids, energy storage systems, energy efficiency and/or electric mobility). This should be based on technical data and information obtained from energy planning processes, national development priorities, climate commitments and relevant innovation and technology indicators (such as data development in Axis 1, some of the indicators listed under Axis 2, and potentially additional energy innovation metrics to be developed); specialized literature; best international practices, etc. Technology areas that are considered strategic ought to be consistent with national plans and strategies. The action lines proposed for this strategic level are as follows:

Action line 1: Understanding what type of energy transition pathway Brazil will follow. International experience shows that there are different types of energy transition: partial or full; low-carbon or carbon-neutral, with different combinations of priority technologies and measures, medium- and short-term, etc. Understanding the type of transition relevant to Brazil is a process that involves identifying the country's needs with regard to energy security and sovereignty, economic growth and competitiveness; considering social and economic aspects such as the democratization of secure, reliable, and sustainable access to energy and what sources of energy are available; and considering the specificities of the national context.

Action line 2: Setting up an Energy Innovation Committee (EIC), or a similar body, with the mission of promoting and ensuring the engagement and coordination of key stakeholders involved in the development and implementation of relevant policies for a big push in the energy sector, including energy policy, climate policy and ST&I policy. Based on international experience, this study proposes a committee formed by government representatives (at ministry level), planning and regulatory bodies and development agencies that are involved in energy planning, as well as climate, ST&I and industrial policies. It is also recommended that the EIC should create participatory mechanisms to support decision-making, aimed at engaging the productive sector and STIs.

Action line 3: Creating a platform to provide evidence-based data and technical input to support EIC strategic decisions. Robust and consistent databases are required in the areas of energy, sustainability, and innovation indicators. This effort should bring together Axis 3, Axis 1 (development of data on expenditure/investments in energy innovation) and Axis 2 (performance indicators for different technologies). This line of action includes investing in reliable databases, especially in areas where data gaps persist, and developing specific indicators to monitor the evolution of innovation in energy, including identifying the technological readiness levels of various energy technologies and pressing technology innovation gaps in the case of Brazil (IEA, 2020a and 2019e).

Action line 4: Setting strategic guidelines and defining priority technology areas for energy transition. This line consists in providing input for the IEC's identification of energy sources that will be part of the country's energy system in the long run, as well as pointing out the changes required to make the system more resilient, efficient, flexible, and sustainable. Although there are no specific plans that coordinate energy, climate and ST&I priorities, there are policies in each of these areas whose objectives already share synergies and points in common, such as Brazil's Ten-Year Energy Plan and its Nationally Determined Contribution (NDC). However, as can be learned from the review of international experience, the country would benefit from establishing explicit coordination mechanisms for these policies, as well as clear priorities in terms of energy innovation.

Action line 5: Setting clear and specific missions for federal agencies. Each should be in charge of specific, clear and complementary missions, so as to avoid overlaps. In doing so, coordination costs will decrease, and agencies will increase their legitimacy before government and society. This, in turn, will make federal agencies and public organizations more resilient to crises and moments of political and institutional instability. In general, ST&I policies should be regularly revised to adapt to a constantly-changing world, and to socioeconomic changes induced by the results of previous policies.

2. Tactical-operational level (technology areas)

The tactical-operational level further defines the technology areas or systems prioritized at the strategic level, as described above. At this level, technical groups of experts and stakeholders should be created for each of the technology areas prioritized by the EIC, with a view to designing technological roadmaps that take into account gaps, obstacles, strengths and opportunities for innovation in each prioritized technology area. The purpose of such roadmaps is to offer evidence-based technical input to prioritize investments in R&D that generate more co-benefits. The lines of action in this tactical-operational level are as follows:

Action line 6: Coordinating stakeholders at the tactical-operational level, given that coordination is a challenge that arises at all levels. One way of establishing such coordination is through the creation of technical committees, as seen in international experience. Such committees would bring together representatives from different sectors, such as STIs, businesses and the government, so that interests, expectations and contributions may be aligned within the scope of each technological system. In other words, for each priority technology family (for example, solar photovoltaic power, or energy efficiency), there would be a technical committee with the task of developing a roadmap for that specific technology. The participation of state companies, the private sector and international organizations in the technical committees should be considered, as well as engagement with advocacy groups and citizens.

Action line 7: Mapping gaps, obstacles, strengths and opportunities for each technology area. In order to better understand the internal needs of each technology areas and its subareas, including different technological and innovative skills and capabilities, it is necessary to identify aspects such as relevant technology readiness levels, power generation potential, local technological skills and capabilities, installed innovation and R&D infrastructure, production capacity, supply chain issues in Brazil and worldwide, and potential business opportunities.

Action line 8: Developing specific roadmaps for each technology area, i.e. plans for the development for technology development, setting clear and specific objectives and goals (or milestones) to be achieved in the short, medium, and long terms. Such roadmaps should take into account the productive and technological capabilities of Brazil's production sector, so as to avoid increasing or perpetuating its dependence on foreign technologies. Roadmaps should be updated regularly, given the constant evolution of the technologies involved, but also provide continuity and ensure durability of support schemes for innovation.

3. Institutional level (incentive mechanisms)

On a third level, incentive mechanisms should be implemented or adapted to foster the development of each priority technology area, whether new or not, so as to turn them into something real and ensure that the pathways defined for each sector are viable. Incentive mechanisms are the tools to achieve the objectives and milestones defined in the roadmaps or technology development plans. The type of energy transition that the country is aiming for ought to be aligned with this entire process. The following lines of action are indicated in general terms. They should be developed in further detail when implementing the lines of action for the previous levels.

Action line 9: Implementing incentive mechanisms and programmes to connect the different stages of the innovation process, considering the most appropriate instruments for each stage (table IV.2). Brazil has researchers and groups of excellence in energy, as well as recognized achievements in several fields of research. However, there is a gap between research achievements (publications and patents) and their practical application. Bridging academic research related to clean energy and the development of technologies effectively applied by the productive sector should be the starting point of a programme aimed at the development of strategic technology areas. Incentive mechanisms to finance Proofs of Concept (PoC) and "fast tracking schemes: from concept to market" can provide ways to bridge basic and applied research and experimental development.

Action line 10: Implementing incentive mechanisms to strengthen knowledge networks, promote collaboration and foster the development of innovation clusters. The mapping exercise carried out under Axis 3 has shown that Brazil has incentive mechanisms in place that are capable of promoting collaborative research focused on innovation, even though these mechanisms are not directly aimed at renewable energies. However, reviewing the experiences of innovation leaders has shown that these countries have adopted robust and bold incentive mechanisms to create clean energy innovation ecosystems. A potential way to mobilize and coordinate innovation actors is through the implementation of an open innovation platform that enables the interaction of large, medium, and small businesses; ST&I centres focused on creating new skills; and business opportunities.

Action line 11: Adapting existing incentive mechanisms. The incentive mechanisms that are active and available in Brazil have the capacity to support the development of clean energies, but they need to be better focused and aligned with the technological roadmaps and guidelines issued by technical committees, as recommended in the previous lines of action. The reorientation of incentive mechanisms should begin with support for academic research (such as programmes led by the CNPq and state research support foundations, for example) and adapt innovation mechanisms in cooperation with or led by the private sector (such as economic subsidies, subsidized credit lines and other types of financing operated by FINEP, BNDES AND EMBRAPII). Sector funds could also be adapted to support innovation in renewable or clean energy sources (CT-Energy, CT-Transport, CT-Biotechnology, CT-Agribusiness, CT-Petroleum, CT-Information).

Action line 12: Implementing long-term R&D and innovation programmes for priority technology areas. The experiences of energy innovation leaders corroborate the notion that the development of strategic technology areas requires long-term programmes and policies. In Brazil, there are no specific long-term mechanisms to encourage R&D and innovation in low-carbon energies —with the exception of the Bioenergy Research Programme (BIOEN) run by the São Paulo State Research Foundation (FAPESP). Although Brazil already has an advanced technology system in areas such as bioenergy, there is constant need for modernization and technological improvement, as well as strengthening the country's position in global value chains, through long-term incentive mechanisms for energy innovation. Long-term programmes should be guided by the technological roadmaps described above.

Action line 13: Implementing demonstration programmes —supporting the experimental testing of technologies, systems or methods in real conditions for their subsequent introduction to the market. Such programmes also bring together energy technology producers (hardware, software and engineering companies) and users (services), and trigger technological learning processes, in addition to being able to create business opportunities related to new energy systems or demands along the supply chain. In the case of Brazil, it is possible to start implementing small-scope demonstration programmes, aiming to respond to technology development demands that can be met mainly with local skills. It is important to highlight that ANEEL's R&D programme has already financed small demonstration projects, but these were isolated initiatives that took place outside the central scope of the programme.

Action line 14: Implementing testing facilities and platforms. One way to strengthen the development of clean energy innovations is through the creation of testing facilities as part of Brazil's public R&D

infrastructure. This type of structure also strengthens relationships among innovation ecosystem actors, and enables the creation of new technology demands and new business opportunities, as tests and experiments present new challenges related to novel energy technologies

Action line 15: Implementing incentive mechanisms to stimulate the commercialization of new energy technologies. As pointed out in Chapter I, the menu of options for sustainable energy is extensive and has expanded with rapid technological development, including non-conventional renewable sources (photovoltaic, wind, sea, hydrogen, etc.), advanced fuels (e.g. second-generation ethanol, aviation biokerosene, renewable electrofuels), smart grids, energy efficiency, etc. These new solutions bring with them wide commercial and business opportunities. All the leading countries analysed under this study have structured programmes to stimulate market access, entrepreneurship, business creation and, especially in the case of technologies developed by STIs, the development of startups focused on clean energy. Brazil has some programmes aimed at investing in startups, such as the Primatec Fund, the Criatec Fund, and FIP Anjo. However, these initiatives focus on capitalizing new businesses, and have a limited reach compared to international experience. The Spark Programme (*Programa Centelha*), managed by FINEP, has a wider approach. It is necessary to develop a set of complementary incentives that are business-focused, and explicitly aimed at the dissemination and commercialization of new technologies. As stated earlier, it is of key importance that STIs support startups, incubators and entrepreneurship training (e.g. networking, guidance on how to do business, support in accessing venture capital, etc.).

Action line 16: Strengthening international partnerships. These partnerships can generate opportunities for productive exchanges —of knowledge, experiences, and resources— or even technological transfers between countries. In the energy area, Brazil is already involved in a series of bilateral partnerships and international forums, including Mission Innovation, the Biofuture Platform, and the Technology Collaboration Programmes by IEA. At the regional level, Brazil has been engaged in peer exchanges and strategic dialogues with Latin American and Caribbean countries, with which it shares similar challenges and which can offer relevant experiences to each other, in addition to discussing prospects for the integration of their energy infrastructures. In addition, Brazil is an active participant in regional energy cooperation forums, such as the Regional Energy Planners Forum; the Regional Observatory for Sustainable Energy (ROSE, which aims to develop, implement and monitor sustainable energy strategies, plans and policies based on objective evidence); and the Regional Political Dialogues on Energy Efficiency, led by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) in collaboration with other entities working at the regional level, including the Latin American Energy Organization (OLADE), the Inter-American Development Bank (IDB), and the International Renewable Energy Agency (IRENA). Although there are many opportunities for international cooperation, the level of engagement depends on each country and its own strategies.

F. Final remarks on incentive mechanisms to accelerate clean energy innovation in Brazil

The recommendations presented in the previous sections reflect the general lines and the main elements that ought to be considered when designing a policy mix for an energy big push in Brazil. This section highlights the key messages and recommendations for such momentum.

Firstly, a Big Push for clean energy innovation in Brazil will only be possible if significant, stable and predictable public funds are mobilized in the short, medium and long terms. In order to achieve that, it is necessary to establish a continuous and sustained budget flow for R&D programmes focused on priority clean energy technologies. A balanced combination of R&D incentive mechanisms (taking into account their degree of uncertainty, and the level of technical and market risk) is essential to drive innovation in low-carbon energy. R&D incentive mechanisms should include different types of incentives, so that innovation projects with higher risk and uncertainty levels can be supported by mechanisms that reduce these challenges, such as economic subsidies, non-reimbursable funding for STI/company collaborative projects, public procurement, and public shareholding. Projects with lower degrees of risk and uncertainty can be supported through subsidized credit and tax incentive mechanisms. In such a model, public resources would focus on incentive mechanisms that reduce uncertainty and risk to unlock innovation, making it more attractive to the productive sector, thus leveraging private investment in R&D. Tax incentives should have a complementary nature.

All stages of the innovative process should be encouraged, from research and development, to demonstration, testing and experimentation, to commercial development and introduction to the market. Not only the supply-side of innovation, i.e. the supply of a new technology, should be taken into consideration. To contribute to the commercial success of a new technology, which depends on demand-side aspects, including scale-deployment, is vital to design incentive mechanisms that promote the profitability of investments in such technology. When fostering diffusion or deployment of new technologies, it is necessary to consider complementary and coordinated policies that operate throughout the value chain, such as some sort of incentive or advantage for consumers who invest in sustainable energy sources; predictable auctions to create growing markets for renewable energy sources combined with funding for electricity generation (conditional on local content requirements); subsidized credit lines for capital goods that are more energy-efficient; and tax incentives (tax relief or exemptions, accelerated depreciation), among others. In the case of variable renewable energies, such as solar and wind, there is a high initial capital cost, and a lower use and maintenance cost, compared to conventional fossil energy sources. Therefore, these energy sources require specific financing arrangements to foster uptake at a scale compatible with the energy transition the country seeks to achieve.

Energy efficiency is a fertile field for development, with great socioeconomic and environmental co-benefits. Incentive mechanisms in the area of energy efficiency (tax exemptions, accelerated depreciation, subsidized credit) should be offered to those companies that consume significant amounts of fossil energy, and which have greater opportunities for reducing greenhouse gas and pollutant emissions, as well as energy costs. Incentives should also be offered to energy consumers.

An ambitious strategy for a Big Push for clean energy innovation should include not only energy production and generation technologies, but also energy systems as a whole, for example including energy distribution, storage technologies, end-use sectors, as well as the integration of emerging energy technologies on existing systems. Digital technologies could be one of the focus areas for a more ambitious strategy, since their cross-cutting character drives progress in the development of several relevant technologies, such as smart grids, smart energy storage systems, and energy efficiency technologies, including the internet of things, automation, artificial intelligence, manufacturing 4.0, etc.

Last, but not least, a Big Push for Sustainability in the energy sector involves the coordination of energy, climate, ST&I and development plans and policies, which not only generate efficiencies and synergies between R&D efforts and invested resources, but also contribute to mobilizing relevant actors and the necessary investments.

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V. Final considerations and future developments

The work carried out within the framework of the Energy Big Push (EBP) project in 2019 enabled significant progress in understanding the role, recent trends, and potential social, economic and environmental impacts, as well as the incentive framework, for innovations in clean and low-carbon energy in Brazil. Guided by the objective of supporting more and better investment for the construction of a sustainable energy system with a focus on innovation, the EBP presents a unique panorama of energy innovation in the country. Based on international metrics, this study provides data, evidence and pathways that can support a Big Push for Sustainability in the Brazilian energy system.

Chapter I presents the Big Push for Sustainability approach, which has been developed to support Latin American and Caribbean countries in the construction of more sustainable development styles underpinned by the social, economic, and environmental tripod. Based on the urgent need to change current development styles, the Big Push for Sustainability is seen as a guiding tool in this structural transformation process. Chapter I introduces the main conceptual elements of this approach, highlighting the relevance of investment for this change (including investments in technological and innovative capacities); the guiding pillars for the construction of new development styles, including the triple efficiency (Keynesian, Schumpeterian and sustainability); and the key role of policy coordination to mobilize and accelerate complementary and scale sustainable investments, which are necessary for the transformation that is aimed at. One of the main findings in Chapter I concerns the great opportunities that sustainable investments in the energy sector, including in innovation, represent for a Big Push for Sustainability, due to their multiple positive impacts on the health of the population; the competitiveness and systemic efficiency of the economy; social inclusion; and the reduction of greenhouse gas emissions.

Chapter II provides a unique overview of energy innovation investments in Brazil, resulting from the work developed under Axis 1 of the EBP. It includes a description of the pioneering efforts made to map, compile, treat and analyse databases on public and publicly-oriented investments in energy research, development and demonstration (RD&D) in the country. According to this analysis, public investment in energy RD&D in Brazil reached its peak in 2014, with a total of R$ 1.1 billion. In addition, most of these investments are focused on renewable energy sources, which accounted for 47% of the total in 2015, even though publicly-oriented investments, which make up most of the energy investments, are mostly dedicated to fossil fuels. Public spending on energy RD&D, including specific investments in innovation in renewable energies, has since declined, from R$ 696 million in 2014 to R$ 217 million in 2018. Furthermore, added together, public and publicly-oriented investments in renewable energy RD&D fell from R$ 966.44 million in 2014 to R$ 488.60 million in 2018, even with the recovery of total energy R&D expenditure observed from 2016 to 2018. In addition to the estimates and analyses of recent trends in RD&D investments in 7 categories and 30 subcategories of energy in Brazil, one of the main contributions presented in Chapter II refers to the development of a process for data collection, treatment, management and analysis. This process represents an important step forward to monitor the evolution of these investments and provide data to support the improvement of policies for the sector. By enabling the monitoring of RD&D expenditures across different energy categories in Brazil, this process can become a beacon for policies aimed at accelerating these investments and, in a way, a tool to gauge the development of a big push for low-carbon energies in Brazil. As this is a pioneering effort, there is ample room for future improvements, especially with regard to harmonizing the available databases so as to obtain a more comprehensive view of investment in energy RD&D in Brazil.

Chapter III, in turn, presents technical-economic, social, environmental and political-institutional variables and parameters for each of the low-carbon energy technologies selected in Brazil, as a result of the work developed under Axis 2 of the EBP. Thus, the various data and evidence presented form a set of indicators that can contribute to informed decision-making, enabling better and well-coordinated investments in RD&D and the design of appropriate incentive mechanisms for the promotion of low-carbon technologies that match the national context. An important finding in this chapter is that there is not a single sector or technology that meets all dimensions of sustainability and, therefore, a coordinated set of investments in different technological energy systems is necessary for the establishment of a diversified, integrated and resilient energy mix, achieving benefits in multiple sustainable development dimensions.

Chapter IV discusses incentive mechanisms that can accelerate investments in clean energy innovation in Brazil, resulting from the work under Axis 3 of the EBP. The chapter summarizes a wide survey and analysis of mechanisms to encourage innovation in Brazil. It demonstrates that most of the mechanisms available to encourage research and development (R&D) in the country are not explicitly focused on the energy sector, and are concentrated on the provision function, and in the form of reimbursable funds. This effort allowed to conclude that, despite multiple existing mechanisms, as well as sectoral policies and plans (energy, transport and climate) that deal with clean energy, Brazil does not have a coordinated and long-term national strategy for low-carbon energy innovation. Chapter IV also presents lessons learned from reviewing the experience of other countries that lead in clean energy innovation, highlighting the importance of a continuous and robust flow of public funds to support long-term R&D activities, consistent with national priorities in the areas of energy, climate, science, technology & innovation (ST&I), and development. Based on these analyses, a set of 16 lines of action and priority instruments was produced to accelerate investment in innovation with a view to enabling energy transition in Brazil.

In general, in addition to the findings under each axis of the Energy Big Push project, a major legacy of the project is the cooperation, dialogue and engagement established among experts from over a dozen entities in the areas of energy, innovation and sustainable development in Brazil, Latin America and the world. Engagement and coordination are crucial aspects of any process aiming to promote more sustainable development styles. Producing and sharing information, knowledge and experiences are key factors for the rapid advancement of science towards the development of increasingly effective solutions to overcome global challenges and transform the current development style. The economic crisis that has been triggered by the COVID-19 pandemic is still unfolding, and will result in one of the biggest economic recessions in modern history. ECLAC estimates that the Brazilian economy should contract by 5.2% in 2020, the biggest drop in over a century. Investment in low-carbon energy will also be highly affected, especially with regard to RD&D, which, as seen in Chapter II, tend to follow the trend of economic cycles. Developing countries such as Brazil, which already faced a slow economic recovery and marked social inequalities before the crisis, may find themselves in a situation of even greater socioeconomic vulnerabilities. Nevertheless, measures to restore economic activity are under discussion, including the expansion of public spending and stimulus packages, which may represent an opportunity to implement measures for a sustainable economic recovery in line with a Big Push for Sustainability.

The post-COVID-19 world calls for the urgent construction of more resilient and sustainable development styles. The pandemic crisis brought about sudden changes in all sectors of the economy, revealing the fragility of the current development style. With the sudden paralysis of several sectors of the economy, the demand for energy is highly affected. Several companies in the sector feel helpless, and many governments have not yet presented measures to guarantee their survival. Never have innovation and adaptability been so vital. This crisis shows the importance of a well-structured, resilient and effective innovation system, capable of preventing and providing quick responses to unforeseen and abrupt events. More than ever, it is necessary to rethink and redesign economic dynamism based on a new generation of long-term policies for sustainable development, capable of promoting the strengthening of the entire innovation system, its public and private actors, as well as promoting the value of more sustainable products and processes. These policies should, therefore, consider substantial investments in ST&I towards sustainability. In this regard, multilateral collaboration is one of the pillars for international R&D in the field of energy, and it can now be deepened and improved.

Post-COVID-19 economic recovery should be based on sustainability, and energy transition is a fundamental part of a more sustainable future. If one wants to build an increasingly connected and digitalized society, access to clean energy ought to be guaranteed to everyone. Attracting investment and strengthening international cooperation will, therefore, be essential for the development of new low-carbon energy technologies and the necessary infrastructure to implement them widely. It is urgent to overcome some of the major challenges facing us, including diversifying the energy mix through the integration of new distributed renewable energy sources; adapting and implementing new transmission and distribution infrastructures; and developing smarter and more efficient services and products (digitization, storage, cargo and network management, for example).

The EBP has made it clear that a significant share of all investment in innovation made in Brazil is strongly linked to economic performance. If, before the COVID-19 pandemic crisis, investment in innovation in Brazil was already timid in comparison with developed countries, the tendency is that these investments will drop even further during the crisis. Therefore, it is essential to design policies and programmes that may guarantee an adequate level of public investment in innovation. Maintaining the activities of the EBP *project*, and indeed turning it into an EBP *process*, will bring to the table important reflections on corporate investment in innovation, and why this investment does not replace public spending on R&D. There are fruitful areas for future developments. What lines of action and incentive mechanisms can be effective to maintain the innovation dynamics in the energy sector and make the sector more resilient to crises and to the impacts of climate change? How can government and businesses cooperate to optimize and coordinate investments in new ideas, new technologies and new business models that may ensure energy security and sustainable development in the country?

Finally, the results presented in this report demonstrate the importance of establishing a permanent process to ensure that information and data that are relevant to a big push in the energy sector are available and accessible to decision makers and the public. In this regard, the construction of an environment capable of making data and information available to all stakeholders, both public and private, is highly strategic for the country, as it can enable well-informed and quick decision-making. This environment can serve as a platform to (1) integrate and systematize up-to-date information and data on public and private investments in R&D in Brazil; (2) introduce a set of investment impact indicators and a set of performance indicators for low-carbon energy technologies; and (3) build a propositional framework of strategic actions and mechanisms to foster innovation that is essential for a sustainable energy transformation. The Energy Big Push project is based on the premise that transparency and access to high-quality evidence and information is the best tool for promoting a big push forward in Brazil's energy sector, especially amidst global crises and major societal challenges.

Annex

Table A1
Energy Big Push Workshop Participants

Ailson de Souza Barbosa (ANEEL)	Georgia Jordan (UnB)
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Today, Brazil and many countries around the world are seeking to stimulate economic recovery and improve people's quality of life. In this context, the Economic Commission for Latin America and the Caribbean (ECLAC) of the United Nations has been developing the Big Push for Sustainability, a renewed approach to support the efforts of the countries of the region to design more sustainable development models, by coordinating policies to promote investments that will transform existing models.

The ECLAC office in Brasilia and the Center for Strategic Studies and Management (CGEE), in conjunction with various partners, developed the Energy Big Push Brazil project, which provides evidence to promote innovation investments for a sustainable energy transition in Brazil. This publication aims to enhance readers' understanding of the energy innovation investment landscape, the performance of low carbon technologies and the policy framework for building clean energy technological competencies, contributing to an energy big push in Brazil.

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