OVERVIEW OF
ENERGY INNOVATION
INVESTMENTS IN BRAZIL

DATA FOR AN ENERGY BIG PUSH

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Project Documents

Overview of energy innovation investments in Brazil

Data for an energy big push

This document was prepared by Bárbara Bressan Rocha, Marcelo Poppe and Mayra Juruá Gomes de Oliveira of the Center for Strategic Studies and Management (CGEE) and by Camila Gramkow of the Economic Commission for Latin America and the Caribbean (ECLAC), based on the project reports produced by André Furtado of the Science and Technology of the Institute of Geosciences of the State University of Campinas (UNICAMP), with support from Silvia de Carvalho of the Economy, Sociology and Technology Department of the Faculty of Agricultural Sciences of São Paulo State University (UNESP) and Lucas Motta of CGEE, and the contributions from experts of the Brazilian Energy Research Office (EPE) and members of the Energy Big Push project – Axis 1 Working Group.

This document was prepared as part of the project "Sustainable development paths for middle-income countries within the framework of the 2030 Agenda for Sustainable Development in Latin America and the Caribbean", one of the technical cooperation activities of ECLAC and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) undertaken in 2018–2020. Within the framework of these activities, the Energy Big Push Brazil project has been carried out, led by the ECLAC office in Brasilia and CGEE, supported by GIZ and the Ministry of Science, Technology and Innovation (MCTI) of Brazil.

This report covers the activities carried out under the second management agreement between CGEE and MCTI – 18º Termo Aditivo/Ação: Internacionalização da CT&I Brasileira /Activity: Inserção do CGEE em Agendas Internacionais – Projeto Agenda Positiva para a Mudança do Clima e do Desenvolvimento Sustentável 52.01.50.01/MCTI/2018.

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United Nations publication
LC/TS.2020/62
LC/BRS/TS.2020/4

Printed at United Nations, Santiago
S.20-00342

This publication should be cited as: Economic Commission for Latin America and the Caribbean (ECLAC)/Center for Strategic Studies and Management (CGEE), "Overview of energy innovation investments in Brazil: data for an energy big push", *Project Documents* (LC/TS.2020/62; LC/BRS/TS.2020/4), Santiago, 2020.

C389Pm

Economic Commission for Latin America and the Caribbean (ECLAC)/Center for Strategic Studies and Management (CGEE), "Overview of energy innovation investments in Brazil: data for an energy big push", *Project Documents* (LC/TS.2020/62; LC/BRS/TS.2020/4), Santiago, 2020.

67 p.: il.

1. Investment. 2 Energy. 3. Innovation. 4. Research and development. 5. Data analysis. I. CGEE. II. Brazil

CDU 620.91: 330.322 (81)

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Contents

Executive Summary **7**

Preface **9**

Introduction **13**

I. Scope **15**

II. Definition of terms and concepts **17**
What is energy "RD&D"? 17
What are the classification criteria for RD&D projects? 18
What criterion is used to calculate RD&D investments? 19

III. Methodology for data collection and analysis of energy RD&D investments **21**
Data classification, structuring and management procedure 23
Methodological challenges 26

IV. Flow of RD&D investments in Brazil **27**

V. Summary presentation of data **29**
FNDCT data 31
FINEP data 32
CNPq data 33
ANP data 34
ANEEL data 35
BNDES data 36
FAPESP data 36
Brazilian Nuclear Programme data 37

VI. Data consolidation and limitations **39**
Public investments in energy RD&D 39
Publicly-oriented investments in energy RD&D 42

R&D programme regulated by ANEEL 42
R&D programme regulated by the ANP 44
Public and publicly-oriented investments in energy RD&D 44
Limitations 48

VII. Next steps 49

Bibliography 51

Annexes 53

Tables

Table 1 Digit-1 and digit-2 technology groups 18
Table 2 Search terms used for the classification of RD&D projects 24
Table 3 RD&D data and funding sources, and their characterization 27
Table 4 Data sources for RD&D projects and analysis of available information 30

Figures

Figure 1 Public energy RD&D investments per year by energy category in Brazil 40
Figure 2 Shares of energy categories in public expenditure on energy RD&D per year 40
Figure 3 Shares of low-carbon and other energy technologies in public expenditure on energy RD&D per year 41
Figure 4 Amount of public investments in renewable energy RD&D 42
Figure 5 Publicly-oriented energy RD&D expenditures regulated by ANEEL 43
Figure 6 Percentage change in Brazilian GDP from 2013 to 2018 43
Figure 7 Publicly-oriented energy RD&D expenditures regulated by the ANP 44
Figure 8 Amount of public and publicly-oriented investments in energy RD&D per year by energy category in Brazil 45
Figure 9 Share of public and publicly-oriented expenditures in energy RD&D per year 46
Figure 10 Shares of low-carbon and other energy technologies in public and publicly-oriented expenditure on energy RD&D per year 46
Figure 11 Amount of public and publicly-oriented investments in renewable energy RD&D 47

Diagrams

Diagram 1 Strategic intelligence meta-process in ST&I 22
Diagram 2 Guiding questions 22
Diagram 3 Intelligence cycle steps 23
Diagram 4 Energy RD&D investment flows 28

Executive Summary

This report presents the work carried out within the framework of Axis 1 of the Energy Big Push (EBP) project, which aimed to develop a process for collecting, structuring and managing data on public and private investments in energy research, development and demonstration (RD&D). The report presents the methodology and tools that enabled the creation of a comprehensive data set on public and publicly-oriented investments in innovation allocated to different categories of energy technologies. It includes a description of the database mapping process; the database analysis; and the development and application of the methodology for the production of innovative statistics on energy RD&D investments in Brazil. In addition, it presents solutions for improving data collection and analysis, as well as statistics on energy innovation in the country.

The concept of research, development and demonstration (RD&D) includes: basic research, when clearly oriented towards the development of energy-related technologies; applied research; experimental development; and demonstration, which includes the design, construction and operation of a technology prototype on a commercial or quasi-commercial scale to provide technical, economic and environmental information to the productive sector, funding entities, regulators, and policy makers. The collected RD&D data cover all types of energy, and is based on the international classification applied and developed by the International Energy Agency (IEA). This wide scope made it possible to understand the relative share of RD&D expenditures on low-carbon and other energy sources within the full amount of investments in energy RD&D. This comprehensive approach also allows for international comparisons with other data based on the IEA classification.

The databases used in this work are maintained by agencies linked to the federal government and the state of São Paulo. The data have different natures and sources: some derive from the federal government's budget or state allocations, or from investments promoted by special funding lines provided by development banks and innovation agencies.

This work has resulted in a new and innovative set of data on the panorama of energy RD&D investments made in Brazil from 2013 to 2018. The figures reveal that the overall funds invested in energy innovation in the country are mainly focused on fossil-fuel technologies, due to the number of RD&D programmes regulated by the National Agency for Petroleum, Natural Gas and Biofuels (ANP). According to our 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 expenditure in 2015, although publicly-oriented investments, which are the majority of investments in energy, are mainly in the area of fossil sources. Among renewable energies, biofuels account for largest volume of investments. Public spending on energy RD&D, including specific investments in renewable energy innovation, has been falling, from R$ 696 million in 2014 to R$ 217 million in 2018. This is due both to the economic crisis and to deep cuts in federal spending. In addition, public and publicly-oriented RD&D investments in renewable energy technologies fell from R$ 966.44 million in 2014 to R$ 488.60 million in 2018, despite the recovery of total expenditure on RD&D in energy observed from 2016 to 2018.

The data collection, treatment, management and analysis process developed within the framework of EBP Axis 1 represents an important step forward to follow the evolution of investment in energy innovation in Brazil, in addition to providing data to support the improvement of policies for this sector. By enabling the monitoring of RD&D expenditures across different energy categories in Brazil, this process can guide policies aimed at accelerating these investments and, in a way, inform a big push for clean energies in Brazil. As this is a pioneering effort, there is ample room for future improvements, especially with regard to harmonizing available databases so as to obtain a more comprehensive view of investment in energy RD&D in Brazil.

Preface

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 (ECLAC/FES, 2019).

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 the EBP final project report. 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 annexes. 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 annex 1). 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, as well as the final report on the project, which summarizes and brings together each axis's results in the light of the Big Push for Sustainability approach.

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, which is the present document: 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; and
- The EBP final project report: A Big Push for Sustainability in Brazil's energy sector: Input and evidence for policy coordination.

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.

Introduction

This report presents the work carried out within the framework of Axis 1 of the Energy Big Push (EBP) project. The main objective of EBP Axis 1 is to develop a process for the collection, treatment and analysis of data on public and publicly-oriented investments in energy research, development and demonstration (RD&D) in Brazil, contributing towards the organization of public databases and the classification of energy RD&D projects. This effort provides a better understanding of the source, destination (in terms of energy technology categories), volumes, and recent trends of RD&D expenditures in the energy sector. In addition, it informs decision makers, policy makers and development agencies, and supports them in the design of clean energy innovation policies or programmes, thus contributing to a big push for sustainability in the energy sector in Brazil.

The quality of the statistics and recommendations contained herein relies directly on the quality of the data collected and the accuracy of the analytical method developed. In this regard, this work is an important exercise in RD&D data collection and classification based on international standards. Its methods ought to evolve continuously in order to improve the quality of and access to strategic information about innovation in the country.

In October 2019, an Energy Big Push workshop was held in Brasilia to present and validate the process we developed, as well as our investment estimates for energy RD&D. All suggestions and comments were analysed and processed, and any necessary adjustments were made. Thus, this report aims to describe the process of mapping, collecting and analysing structured and unstructured data on public and publicly-oriented investments in energy RD&D. It also seeks to present an overview of these investments based on the process we developed, as well as pointing out its limitations and recommendations for the future improvement of results.

Good data inform good decisions. Thus, the work carried out under Axis 1 seeks to overcome the challenge of safely reporting on 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 this evidence-based knowledge can be used to support coordinated decisions for a big push for sustainability in the country's energy sector, contributing towards a more economically, socially, and environmentally sustainable development trajectory.

This report is organized as follows: after this introduction, Chapter I presents the scope of this work. Chapter II presents the concepts and definitions that are being used, and Chapter III discusses the methodology developed for data collection and analysis, and the challenges we faced. Chapter IV describes the flow of RD&D investments in Brazil, and Chapter V contains an analytical study of the databases used. Chapter VI presents the estimated investments in energy RD&D and their limitations; and finally, Chapter VII provides guidance on how to organize data, and how to improve the process adopted for this study.

I. Scope

The scope of Axis 1 of the Energy Big Push (EBP) project focused on government data sources. Access to these data is regulated by Brazil's Freedom of Information Law[1] (LAI, in the Portuguese acronym), which mandates transparency and accountability for all government agencies. As a result, we had open access to structured data on public and private investments in research, development, and demonstration. 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)[2]. The latter investments are classified as publicly oriented. Data from state-owned enterprises in the energy sector, such as Petrobras and Eletrobras, which are not subject to public policies, have not been included in this study.

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: 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); the Brazilian Electricity Regulatory Agency (ANEEL); the National Agency for Petroleum, Natural Gas and Biofuels (ANP); the National Bank for Economic and Social Development (BNDES); the National Nuclear Energy Commission (CNEN); and the São Paulo State Research Foundation (FAPESP).

The activities 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

[1] Brazil's Freedom of Information (LAI) was enacted on 18 November 2011 as Law No. 12,527, and came into force six months later (Decree No. 7,724 dated 16 May 2012). LAI established mandatory accountability for any and all bodies and entities linked to direct and indirect administration (including state-owned enterprises, mixed-capital companies, and other entities controlled directly or indirectly by the State), as well as private non-profit organizations that receive public funds. More information available at: https://www.justica.gov.br/Acesso

[2] The PD&I clause is a mandatory clause in all concession, permission and authorization contracts for the generation, transmission, and distribution of electricity, as well as for the exploration, development, and production of oil and natural gas (ANP, 2019c).

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).

When dealing with funds invested directly by the government, we used budgeted amounts. There are advantages to considering budgeted, rather than executed amounts: first, it is easier to update data series; and second, each expenditure's socioeconomic objectives are clearer in the budget, which directly reflects decisions on resource allocation. These are important advantages from the point of view of designing and evaluating research and development policies (Hollanda, 2003).

Before introducing the specific characteristics of the analysed data sources, it is necessary to present the terms and concepts adopted for the purposes of this work, and how they can describe RD&D investment flows in energy technologies.

II. Definition of terms and concepts

What is energy "RD&D"?

For the purposes of this work, the following research and development (R&D), and research, development, and demonstration (RD&D) concepts will be adopted.

"Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge —including knowledge of humankind, culture and society— and to devise new applications of available knowledge". (Frascati Manual – OECD, 2015).

According to the Frascati Manual (OECD, 2015), the term research and development R&D covers three activities:

(1) **Basic research**: experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.

(2) **Applied research**: original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.

(3) **Experimental development**: systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed.

The R&D definition adopted by the International Energy Agency (IEA) and this work also includes demonstration, defined as:

Demonstration: the design, construction, and operation of a prototype of a technology at or near commercial scale with the purpose of providing technical, economic, and environmental information to industrialists, financiers, regulators and policy makers.

Energy RD&D efforts reported in the IEA's RD&D Manual (2011) include research, development and demonstration, as defined above, when the work applies to technologies used to extract, convert,

generate, transport, distribute, control and use energy. In this context, energy ought to include the entire chain of primary forms found in nature; passing through secondary forms, which are more convenient for transport and storage; up to end uses, such as heat, light, driving force, and other energy services.

In this sense, the concept of energy research and development adopted in this project is the same adopted by the IEA, and differs from the concept of research and development in the Frascati Manual, in that: (i) it focuses only on energy-related programmes; (ii) it includes "demonstration projects"; and (iii) it includes state-owned enterprises (IEA, 2011).

What are the classification criteria for RD&D projects?

The classification criteria for energy RD&D projects adopted in this work are the same used by the IEA (IEA, 2011), organized on two levels: a first level with 7 categories; and a second level with 30 subcategories, referring to energy technology groups. 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 1 shows the digit-1 and digit-2 categories adopted for the classification of projects.

Table 1
Digit-1 and digit-2 technology groups

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 (CO_2) 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 Power 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.

This classification poses a challenge to the project, since each agent promoting RD&D in Brazil has their own structured databases with different attributes and variables. Such databases have no field to classify projects by technology with a correlation to the IEA classification. Thus, this identification should be made by reading the titles and descriptions of RD&D projects. The large volume of projects to be classified requires a semi-automated and robust analysis method that facilitates the identification of projects in each of the analysed databases.

What criterion is used to calculate RD&D investments?

According to the Frascati Manual (OECD, 2015), research and development (R&D) projects should be presented in a separate column from demonstration projects. However, given the difficulty of separating R&D from demonstration projects, the data presented herein refer to RD&D.

When reporting R&D budgets, the Frascati Manual stipulates that multi-annual projects, independently of whether they are budgeted in just one year or in several years, should be allocated to the data referring to the year(s) in which they were budgeted, and not when they are performed. When reporting on multi-annual budgets, the budget profile (if available) should be used to distribute funds over the years of multi-annual projects. If no budget profile is available, funds should be allocated equally throughout the year. Thus, for the databases whose budget amount was used, the total budget for each project was distributed throughout its contract execution period.

III. Methodology for data collection and analysis of energy RD&D investments

Between 2018 and 2019, the EPE developed a first database of public and publicly-oriented investments in (RD&D), using 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. This first initiative was expanded in this study, incorporating other data sources, and extending the series to other years. For this expansion, 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 (see diagram 1).

Having identified our information needs, we designed the questions in diagram 2 to guide the search of the databases.

The procedures shown in diagram 3 were adopted to guide steps 2, 3 and 4 in the Intelligence Cycle.

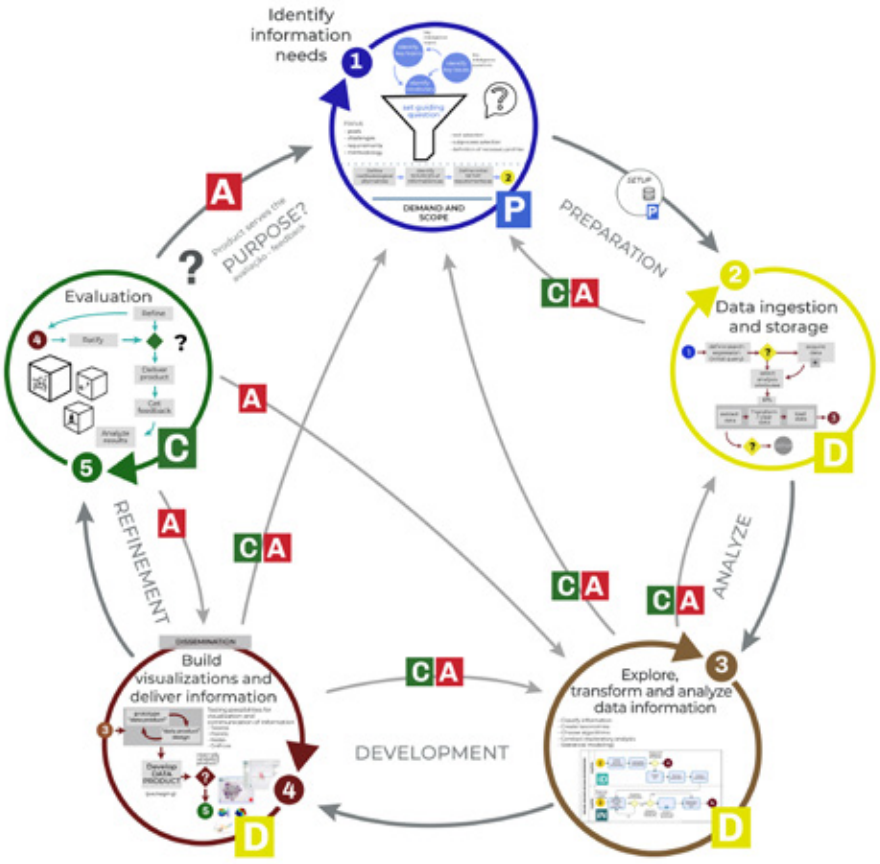
In procedure 1 (diagram 3), public databases containing investments that are considered public or publicly-oriented were mapped and collected. After collecting the databases, all of them had their data fields analysed to assess their feasibility considering the objectives of the study. The minimum essential criteria for using the databases in this first project-classification effort were:

- Data source;
- Project title and/or description;
- Contracted and/or executed amount; and
- Contract date and/or start date and end date.

Some desirable criteria were also selected for the purposes of characterizing databases:

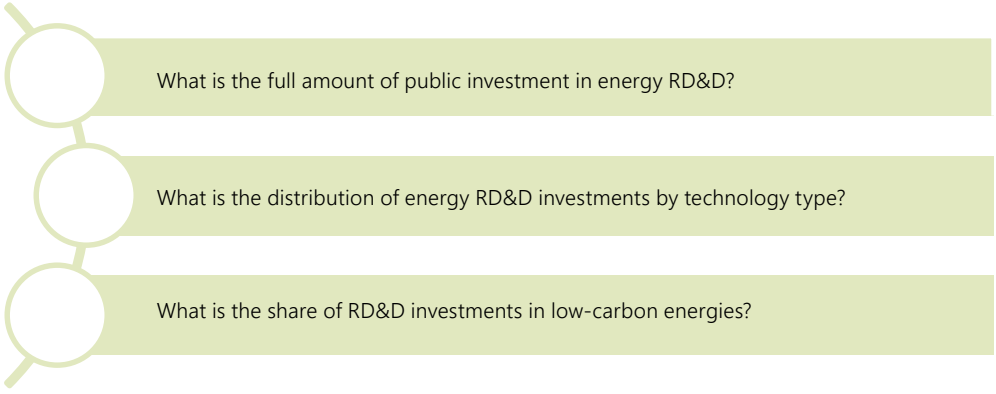
- Destination institution or executing agent;
- Type of support: reimbursable or non-reimbursable;
- Technology Readiness Level (TRL): Research & Development, or Demonstration;
- Funding source; and
- Federative unit.

Diagram 1
Strategic intelligence meta-process in ST&I



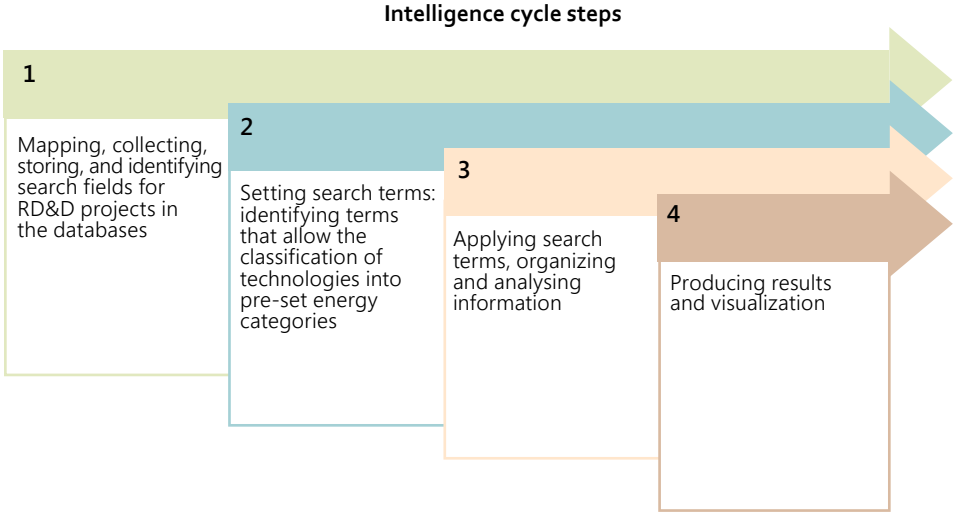
Source: Created by the authors based on Center for Strategic Studies and Management (CGEE), "Desenho e detalhamento do primeiro nível do metaprocesso Inteligência Estratégica em CTI", *Projeto Modelagem e Automação de Processos Finalísticos*, Centro de Gestão e Estudos Estratégicos, Ministério da Ciência, Tecnologia e Inovação e Comunicações, Brasília, December 2017.

Diagram 2
Guiding questions



Source: Created by the authors.

Diagram 3
Intelligence cycle steps



Source: Created by the authors.

Procedure 2 ought to be performed by an energy expert. After defining the search terms, a search algorithm (procedure 3) was used to classify projects in the databases that had been collected and treated for each of the categories (digit-1 and digit-2). Finally, the last procedure was producing and validating results, and generating visualizations. Procedures 3 and 4 generated a list of data analysis protocols for each database considered in this study, which can be found in annex 7 of this report.

Data classification, structuring and management procedure

Based on our objective, which includes measuring RD&D investments in the Brazilian energy sector, and on our proposed guiding questions (diagram 2), special attention was given to the identification, in existing databases, of the shares allocated to energy RD&D, subdivided by energy technology group. Thus, table 2 shows digit-1 and digit-2 categories, as well as the search terms used to select projects and classify them according to the proposed categories.

The search terms presented in table 2 guided the initial search, but adjustments were made later to each database. The exercise of applying search terms to project titles or description fields was done through an R programming language algorithm. The protocols developed for each of the databases in order to identify and allocate projects to each energy category are available in annex 7 of this report.

Table 2
Search terms used for the classification of RD&D projects

Digit 1	Energy Technology Groups	Digit 2	Synthetical Categories	Categories	Keywords or search terms
1	Energy Efficiency	1.1	Energy efficiency technologies applied to industry	Energy efficiency technologies applied to industry: assembling procedures, industrial processes, equipment, and systems; life-cycle analysis	*motor** (engine*, or motor*); *"máquina* elétrica*"* (electric machine*); *equipamento** (equipment*); *"sistema* elétrico*"* (electric system*); *aparelho** (device*); *etiquetagem* (labelling); *metrologia* (metrology); *"processo* industria*"* & *"eficiência energética"* (industrial process* & energy efficiency)
		1.2	Energy efficiency technologies applied to households and businesses	Energy efficiency technologies applied to households and businesses: equipment used in homes and commercial buildings (lighting, refrigeration, heating, appliances, and other electrical and electronic devices; batteries for residential or commercial use)	*"conforto térmico"* (thermal comfort); *edifício** (building*); *edificaç** (building*); *"conforto ambiental"* (environmental comfort); *habitaç** (housing); *iluminação* (lighting); *lâmpada** (light bulb*); LED; *resfriamento* (cooling); *refrigeração* (refrigeration); *compressores* (compressors); *"bomba de calor"* (heat pump*)
		1.3	Energy efficiency technologies applied to the road transport sector	Energy efficiency technologies applied to road transport (vehicle batteries, electric vehicles, hybrid vehicles, electric car infrastructure, efficient combustion engines) and non-road transport (trains, aeroplanes, ships)	*"bateria*"* & *"transporte"* or *"veículo"* (transport or vehicle & batter*); *"veículo* elétrico*"* (electric vehicle*); *motor** & *gasolina* or *diesel* or *etanol* & *eficiente** (efficient & gasoline or diesel or ethanol & engine*/motor*)
		1.4	Other energy efficiency technologies	Other energy efficiency technologies	*eficiência* & *energética* (energy & efficiency)
		1.9	Other unallocated energy efficiency		
2	Fossil Energy Sources: Oil, Natural Gas, and Coal	2.1	Oil and natural gas	Advanced oil and natural gas recovery	*petróleo* (oil, or petroleum); *óleo* (oil); *"gás natural"* (natural gas); *gás* (gas); *"xisto betuminoso"* (oil shale); *hidrocarboneto** (hydrocarbon); offshore; *plataforma de petróleo* (oil platform*); *semissubmersível* (semi-submersible); fpso; *"árvore de natal"* (Christmas tree); *"construção naval"* (shipbuilding); *reservatório** (reservoir); *"recuperação avançada"* (advanced recovery); *geoengenharia* (geoengineering); *escoamento* (flow); *bombeamento* (pumping); risers; *refino* (refining); *"derivados de petróleo"* (oil products); *gasolina* (gasoline, or petrol); *"óleo diesel"* (diesel); *nafta* (naphtha); *combustão* & *petróleo* or *"gás natural"* or *"derivados de petróleo"* (oil or natural gas or oil/petroleum products & combustion) *"turbina a gás"* (gas turbine); *"turbina a vapor"* (steam turbine); *"turbina de avião"* (aircraft turbine); *"geradores a diesel"* (diesel generators); *dutos* (ducts); *oleodutos* (oil pipelines); *tanques* (tanks); *gasodutos* (gas pipelines); *GNL – gás natural liquefeito* (LNG – liquefied natural gas); *armazenamento* & *petróleo* or *"gás natural"* or *"derivados de petróleo"* (oil or natural gas or oil products & storage)
				Refining, transport and storage of oil and natural gas	
				Extraction and production of oil and unconventional natural gas	
				Combustion of oil and natural gas to for energy generation and cogeneration	
		2.2	Coal	Coal extraction, processing, and transport;	*carvão* (coal); *carvão mineral* (coal); *combustão* & *carvão* (coal & combustion); *conversão* & *carvão* (coal & conversion)
				Coal combustion and conversion;	
		2.3	Carbon dioxide (CO_2) separation, capture, transport and storage	CO_2 separation and capture;	*captura* & *CO_2* (CO_2 & capture); *separação* & *CO_2* (CO_2 & separation); *escoamento* & *CO_2* (CO_2 & runoff); *armazenamento* & *CO_2* (CO_2 & storage)
				CO_2 transport and storage;	
		2.9	Other unallocated fossil fuel technologies	Other technologies related to oil, natural gas, and coal.	

Table 2 (continued)

Digit 1	Energy Technology Groups	Digit 2	Synthetical Categories	Categories	Keywords or search terms
3	Renewable Energy Sources	3.1	Solar power	Solar power (heating and cooling, solar photovoltaic, concentrated solar power, other solar power)	*energia* & *solar* (solar & power); *aquecimento* & *solar* (solar & heating); *arrefecimento* & *solar* (solar & cooling); *fotovoltaica* (photovoltaic); *"célula* solar*"* (solar cell*); *"módulo* fotovoltaico*"* (photovoltaic module); *"sistema* fotovoltaico*"* (photovoltaic system*); *solar* & *térmica* (solar & thermal); *concentrador** & *solar* (solar & concentrator*); *heliotérmica* (concentrated solar power, or CSP); *aplicaç** & *alta* & *temperatura* (high & temperature & application*)
		3.2	Wind power	Wind power (onshore and offshore technologies, wind farms, and other technologies)	*energia* & *eólica* (wind & power); *eólicas* & *onshore* (onshore & wind); *eólica** & *offshore* (offshore & wind); *usina* de vento* (wind farm*, or park*, or plant*); *turbina* & *eólica* (wind & turbine); rotor; *aerogerador** (aerogenerator*); *conversor** (converter*); *pás* & *eólica* (winde & blade*)
		3.3	Ocean energy	Ocean energy (tidal energy, wave energy, others)	*energia* & *oceânica* (ocean & energy); *energia* & *maré** (tid* & energy); *energia* & *ondas* (wave & energy); *poder* & *gradiente* & *salinidade* (salinity & gradient & power)
		3.4	Biofuels	Biofuels (bioethanol, biodiesel, other liquid biofuels, solid biofuels, biogas, heat generation applications, and electricity from biomass)	*biocombustível** & *líquido** (liquid & biofuel*); *biocombustível** & *sólido** (solid & biofuel*); *biogás* (biogas); *biomassa* (biomass); *etanol* (ethanol); *bioetanol* (bioethanol); *cana-de-açúcar* (sugar cane); *bagaço* (bagasse); *palha* (straw); *bioeletricidade* (bioelectricity); *gaseificação* (gasification); *pirólise* (pyrolysis); *resíduo** (residue*, or waste); *glicerol* (glycerol); *enzima** & *hidrólise* (hydrolysis & enzyme*); *"hidrolise enzimática"* (enzymatic hydrolysis); *hidrólise* & *ácida* (acid & hydrolysis); *lignocelulose* (lignocellulose); *biocombustível* & *segunda* & *geração* (second & generation & biofuel); biodiesel; *"óleos vegetais"* (vegetable oils); *oleaginosa** (oilseed); *gordura* anima** (animal fat*); *óleo de soja* (soybean oil); *transesterificação* (transesterification); *esterificação* (esterification); *algas* (algae); *microalga** (microalga*); *"biocombustível* de terceira geração"* (third generation biofuel*); *biorreator* (bioreactor)
		3.5	Geothermal energy	Geothermal energy	*"energia geotérmica"* (geothermal energy); *energia* & *recurso** & *hidrotermal** (hydrothermal & resource & energy); *energia* & *recurso** & *rocha** & *seca** & *quente* (hot & dry & rock & resource & energy); *rocha* & *perfuração* (rock & drilling); *rocha* & *exploração* (rock & exploration)
		3.6	Hydroelectricity	Hydroelectricity (small and large)	*hidroeletricidade* (hydroelectricity); *centra* hidroelétrica** (hydroelectric plant*); *pch* (shp); *pequena* centra* hidroelétrica** (small hydroelectric plant*); *UHE* (HPP); *barrage** (dam*); *turbinas hidroelétrica** (hydroelectric turbine*)
		3.7	Other renewable energy sources	Other renewable energy sources	*fontes* & *energia* & *renovável** (renewable & energy & source*)
		3.9	Other unallocated renewable energy sources		
4	Nuclear Fission and Fusion	4.1	Nuclear fission	Nuclear fuel (uranium extraction and processing, uranium enrichment, other nuclear fuels)	*"fissão nuclear"* (nuclear fission); *urânio* (uranium); *enriquecimento* (enrich*); *"combustível nuclear"* (nuclear fuel); *reatores* & *nuclear* (nuclear & reactors); *"usina* nuclear*"* (nuclear plant*); PWR; BWR; *resíduo* & *nuclear* (nuclear & waste); *radioisótopos* & *nuclear* (nuclear & radioisotopes); *"regenerador nuclear"* (nuclear regenerator)
				Nuclear reactors (PWR, super-generators, other reactors)	
				Nuclear waste treatment, storage, and containment	
		4.2	Nuclear fusion	Nuclear fusion	*fusão* & *nuclear* (nuclear & fusion); *fusão* (fusion)
		4.9	Other unallocated fusion and fission	Other unallocated fusion and fission	*energia* & *nuclear* (nuclear & energy)
5	Hydrogen and fuel cells	5.1	Hydrogen	Hydrogen production and storage, hydrogen transport and distribution, other hydrogen infrastructure and end-use systems (excluding fuel cells and vehicles)	*hidrogênio* (hydrogen); *produção* & *hidrogênio* (hydrogen & production); *armazenamento* & *hidrogénio* (hydrogen & storage); *transporte* & *hidrogênio* (hydrogen & transport); *distribuição* & *hidrogênio* (hydrogen & distribution); *infra-estrutura* & *hidrogênio* (hydrogen & infrastructure); *sistema* & *hidrogênio* (hydrogen & system);
		5.2	Fuel cells	Fuel cells (stationary and vehicle applications)	*"célula* a combustível"* (fuel cell); *aplicaç** & *estacionária** or *móvel** (stationary or mobile & application*)
		5.9	Other unallocated hydrogen and fuel cells	Other unallocated hydrogen and fuel cells	

Table 2 (concluded)

Digit 1	Energy Technology Groups	Digit 2	Synthetical Categories	Categories	Keywords or search terms
6	Other Power and Storage Technologies	6.1	Other generation technologies	Power generation (generation, support technologies, and others)	*"geração de energia elétrica"* (power generation); *"tecnologia* de geração de energia elétrica"* (power generation technolog*); *"gerador* de energia elétrica"* (power generator*); *alternador** (alternator*); *cogeração* (cogeneration); *caldeira** & *"energia elétrica"* (power & boiler*)
		6.2	Transmission, distribution	Transmission and distribution (transmission and distribution technologies, distribution networks, control and integration systems, others)	*"transmissão de eletricidade"* (power transmission); *condutor** (conductor*); *supercondutor** (superconductor*); *"conversor* AC/DC"* (AC/DC converter*); *"distribuição de eletricidade"* (power distribution); *"rede de energia elétrica"* (power grid); *"rede* inteligente*"* (smart grid*); *"carga elétrica"* (electric charge); *sistema** & *controle* or *integração* (control or integration & system*)
		6.3	Energy storage	Energy storage (excluding transport), power storage, heat storage	*armazenamento* & *energia* (energy & storage); *armazenamento* & *elétrico* (power & storage); *armazenamento* & *térmica* (heat & storage); *bateria* not veículo** (batter* not vehicle*)
		6.9	Other unallocated generation and storage technologies	Other unallocated generation and storage technologies	
7	Other Cross-cutting Technologies	7.1	Analysis of energy systems	Analysis of energy systems	*sistema** & *energ** (energy & system*); *modelag** & *energ** (energy & model*); *planejamento & energ** (energy & planning); *planejamento* & *sistema* & *energ** (energy & system & planning); *algoritmo* & *energia* ou *eletricidade* (energy or power & algorithm)
		7.2	Basic energy research	Basic energy research	*pesquisa* & *básica* & *energia* (basic & energy & research)
		7.3	Other	Other	

Source: Created by the authors.

Methodological challenges

This project provided a comprehensive overview of public and publicly-oriented investments in research, development and demonstration in Brazil, according to the classification adopted by the IEA. It is important to point out that an additional effort ought to be made both towards improving the search terms, and identifying new databases with more information on the projects. The main methodological challenges that we faced were:

- Organizing different databases into a single harmonized database;
- Defining search terms that might be applicable to each of the structured databases so as to enable the classification of energy RD&D projects;
- Separating data on funding sources from actual project execution. This type of data would help to provide a deeper understanding of RD&D flows in Brazil's science and technology system;
- Identifying which stage of research, development, and demonstration each project refers to. This information is not available in the data sources analysed by us, and therefore the results are presented in aggregated form;
- Accessing data from other federal public entities that fund RD&D in Brazil. At federal level, the Ministry of Education and the Ministry of Agriculture are not included in this study;
- Access data from other state entities that fund RD&D. At state level, only FAPESP was included in this study, which is the main state research agency in Brazil. Other state research support foundations (FAPs) should be included in the next cycle.

In order to address these challenges, the method ought to be continuously improved, and new databases should be included in the study. The next chapter describes the flow of energy RD&D investments, and can help to understand Brazilian statistics on energy RD&D investments.

IV. Flow of RD&D investments in Brazil

In this study, the term publicly-oriented investment refers to loans of any nature for research, development, and demonstration (RD&D) made by public financial institutions, such as the BNDES and FINEP, with financing rates that are more advantageous than market rates. Likewise, RD&D investments made by companies under electricity and oil concession contracts —namely the research and development (R&D) programmes regulated by ANEEL and the ANP— are also considered publicly-oriented investments. The main reason for this classification is that private investment would probably not occur if not driven by public policies and incentive mechanisms.

Table 3 presents the main data sources —all from public authorities— analysed in this study. It 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.

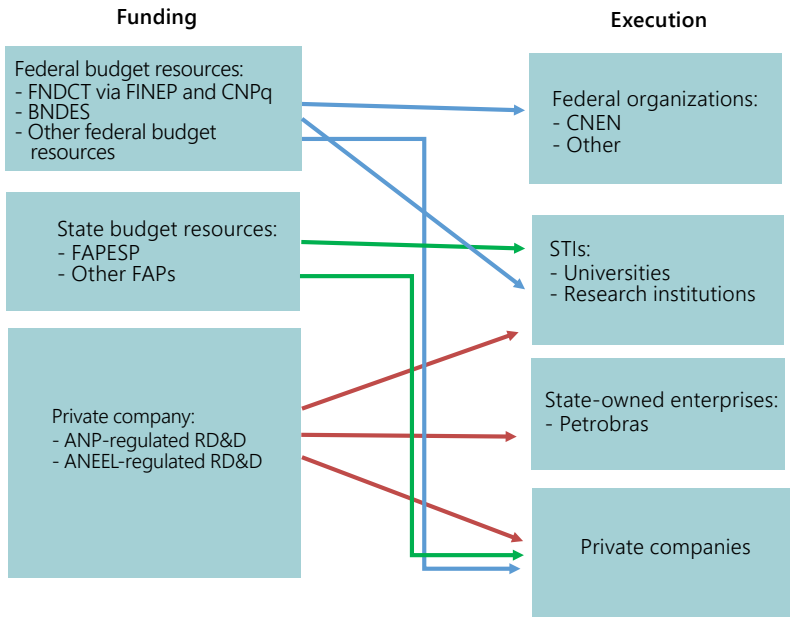
Table 3
RD&D data and funding sources, and their characterization

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

Source: Created by the authors.

Diagram 4 shows the flow of public investments made by public agencies, science and technology institutions (STIs), and companies. It also reveals that some commercial resources (both public and private) are managed by STIs and other organizations, such as FAPESP and other FAPs in the country.

Diagram 4
Energy RD&D investment flows



Source: Created by the authors.

V. Summary presentation of data

In the light of the guiding questions presented in Chapter III, which aim to quantify national investment in energy, we collected information from public databases and assessed the parameters available in them to check whether they could be used for the proposed methodology. Table 4 presents the result of this assessment, and describes the most important information from those databases. The applicability assessment was made based on the criteria presented in Chapter III of this report. In order for projects to be allocated to each of the energy technologies listed in table 1 (from 2013 to 2018), the analysed databases need to describe a research project, which is the statistical unit to which all other information in the database refers.

The most relevant information on the projects contained in the databases is the title and/or a more detailed description of the activities. This enabled us, through the use of search terms, to assign each project to a certain energy technology group. In addition, projects should contain information on the amount of resources allocated, and their distribution over time. It is also desirable (albeit not essential) to have information on the executing entity, as this identifies the direct beneficiaries of the funding. In some situations, the source of funding and the nature of the loan (whether reimbursable or not) may also be relevant. However, this is not included in the scope of this study.

Table 4
Data sources for RD&D projects and analysis of available information

Data provider	FNDCT	FINEP	ANP – RT3 Projects – 2015	ANEEL	BNDES	FAPESP
Project identification code	No	No	Yes	Yes	Yes	Yes
Budgetary unit	FNDCT	FNDCT				
Project title	Yes	Yes	Yes	Yes	No	Yes
Summary/ Keywords/ Objective/Outcome	No	No	Objectives	Detailed description	Brief description	Summary
Activity qualification (BR/AR/ED/D)	No	No	Yes	Yes	Yes	Knowledge area
Technology area	All	All	Oil and natural gas/renewables	Electricity/ renewable	All	Bioenergy
Agency	FINEP CNPQ	FINEP	ANP	Tenderer	BNDES	FAPESP
Contracted amount	Yes	Yes	Yes	Yes	Yes	No
Disbursed amount	No	Yes	No	Yes	Yes	No
Term Contract year	1999–2019	2002–2019	2016–2019	2008–2019	2002–2019	1994–2019
Base term	Jan/1999– Feb/2019	Aug/2002– Mar/2019	Mar/2016– Jun/2019		Jan/02– Mar/2019	Jan/1994– Mar/2019
Project term	Yes	Yes	Yes	Yes	No	Yes
Funding source	FNDCT	FNDCT, STIs other actions	Company	Company	FAT funds Treasury FUNTEC	State tax revenue
Executing institution	Yes	Yes	Yes	Yes, but on the PD RF Database Team.	Client Private companies	Yes
Type of support	Non reimbursable	Non-reimbursable and reimbursable grants	Non reimbursable	Non reimbursable	Reimbursable and non reimbursable	Non reimbursable
Additional information required to answer guiding questions	Amount description or summary	Description or summary	Extend the period, and search data for 2014–2018; project term is missing.	It will be necessary to integrate PD Text Search to RF Team.	Define project execution period.	Financed amounts, expand to other energy sources.
Comments	Database overlaps with FINEP's, but also contains data from CNPq.	Look for details to expand categories by type of energy and technologies.	Include project objective; broken down by area, theme, and sub-theme, to enable categorization; qualification: basic applied research; development.	Very complete database, with details of data, description, justification, and applicability.	Very complete database, with details on date, client, corporate tax registration number (CNPJ), company size, guarantees, etc.	Complete database with area, sub-area, subject, partnerships, summary. It is possible to download the entire database through the website, but it does not contain the financed amounts. Formal access request is required due to confidentiality.
Which base columns could be used to classify projects and answer guiding questions?	This database is limited, with project data and disbursed amount missing. However, it includes data on FNCT projects operated by CNPq.	Instrument, title, contract reference number, tenderer, performer, launch date, term of use, amount released.	Title, contract reference number, waiting time, interpreter, released amount, instrument.	Project code, status, bidder, interpreter (RF team), title, theme, product type, year, year completed, total cost performed.	Client, project description, contract number, contract date, type of support, financial instrument.	

Table 4 (concluded)

Data provider	FNDCT	FINEP	ANP – RT3 Projects – 2015	ANEEL	BNDES	FAPESP
Is the database useful to meet our objectives?	Yes, the database can be used within the proposed method.	Yes, the database can be used within the proposed method.	No, the database is not viable, as it can generate an unwanted distortion in the time series, due to the fact that we only have projects with values in the 2016–2019 period. Complementary data are required.	Yes, the database can be used within the proposed method.	Yes, the database can be used within the proposed method.	Yes, the database can be used within the proposed method, but project amounts can only be obtained through a direct request to FAPESP.
With a view to avoiding duplication, which databases may contain data from other databases?	Non-reimbursable FINEP investments will be a ccounted for through this database.	To avoid duplication, this database will be used only for reimbursable investments.	There is no risk of duplication, except with Petrobras R&D investment data.	There may be some duplication with Petrobras and Eletrobras R&D investment data.	No risk of duplication.	

Source: Created by the authors.

FNDCT data

The National Science and Technology Development Fund (FNDCT) is an accounting fund created in 1969 to finance science and technology development and innovation, with a view to promoting the country's economic and social development (FINEP, 2019).

FNDCT resources are invested through two budgetary units (UO, in the Portuguese acronym):

- UO 74910 – Funds under the supervision of FNDCT, whose budget is part of the Federal Government's Official Credit Operations Fund, which concentrates resources used to finance companies (0A37) through loans to FINEP; and
- UO 24901 – for discretionary FNDCT expenses, i.e. non-reimbursable activities to support STIs and special operations (economic subsidies to companies, investment, resource equalization and liquidity guarantees), in addition to contingency reserves.

UO 24901 gets, through the Annual Budget Law (LOA), 75% of the estimated budget for the year, while UO 74910 gets the remaining 25%, which are financial expenses that are not subject to payment limits or commitments (FINEP, 2019).

The FNDCT's budget structure can be divided into three main groups: vertical actions, cross-sector actions and special operations. Vertical actions and cross-sector actions are those aimed at supporting research, technological development, and innovation projects of individual STIs, in cooperation with companies, or in the form of consortia with the participation of other STIs. In cross-sector actions, unlike vertical actions, there is no need to invest resources in a specific sector. Special operations are those aimed at supporting companies, subdivided into equalization of interest rates, economic subsidies, investment in innovative companies, and incentives for investment through the implementation of liquidity guarantee instruments.

Vertical actions comprise the Science and Technology Sectoral Funds, which were created in 1999 to finance research, development and innovation projects in the country. There are a total of 16 Sectoral Funds, 14 of which are specific to just one sector (CT-Agribusiness; CT-Aeronautics; CT-Amazon; CT-Waterway; CT-Biotechnology; CT-Energy; CT-Space; CT-Hydro; CT-Info; CT-Auto Innovation; CT-Mineral; CT-Health; CT-Petroleum; and CT-Transport), and two are cross-sector. Out of these, one aims at university-business interaction (FVA – Fundo Verde-Amarelo, or Green-and-Yellow-Fund), while the other aims at supporting the improvement of STI infrastructure (CT-Infrastructure). Almost all sectoral funds may include projects related to energy. Two of them, however, are specifically focused on energy production and transformation (CT-Energy and CT-Petroleum).

The FNDCT database released by the MCTI is quite thorough. It contains 31,481 records covering the period between 2013 and 2018, and includes investments made in all sectoral funds. Almost all sectoral funds include energy projects. Therefore, those relating to the categories within the scope of this study were filtered using the search terms selected during this stage of methodology implementation (Chapter III).

This database broadly serves the purposes of our project, as it allows the aggregate measurement of investments by sectoral fund. It also provides information on implemented projects, according to each fund, including details on contracted and executed amounts, start and end date, operating agency, executing institution and destination. In addition, it covers the project reference period corresponding to 2013–2018.

However, the database does not present a project summary and/or keywords –only the titles. Due to the reduced number of words in the titles, the use of search terms to classify investments according to energy categories can generate results with a margin of error (plus or minus).

After applying the search terms, an analysis of all selected projects was made, and those that did not correspond to energy projects were excluded from the classification. Thus, after applying the search terms, there is a chance that projects in the area of energy have not been classified as such, which points to the need of adding new information fields to the database and/or improving the search terms used for future analysis. The application of search terms, as performed in this step, led to underestimated values for FNDCT energy investments. Only 1,558 projects were selected as energy projects, which corresponds to 5% of the total number, and 5.6% of full amount of all FNDCT projects.

In addition, the FNDCT/MCTI database provides information that enable the identification of cross-sector investments. As defined in July 2004 by the Sectoral Funds Coordination Committee, cross-sector actions were strategic programmes run by the MCTI that upheld the Federal Government's Industrial, Technological and Foreign Trade Policy (PITCE) in force at the time. Public calls use resources from several Sectoral Funds simultaneously. This category also includes three cross-sector actions designed to support STIs: 1) supporting events; 2) funding studies and research, technological development & innovation (R, D & I) in different areas of knowledge; and 3) promoting Research and Development in Basic and Strategic Areas (also known as "Cross-sector Actions"), as authorized by article 14 of Law No. 11,540/2007, and aimed at financial actions identified in accordance with the guidelines that govern ST&I, national policy, and the priorities of the national industrial and technological policy.

The FNDCT/MCTI database presents the type of support under which investments were released, making it difficult to identify the volume of resources allocated to each instance, since, according to FINEP (2019), FNDCT funds can be used in the following ways:

(1) Non-reimbursable, to finance STI projects and cooperation projects between companies and STIs, provide economic subsidies to companies, and equalize financial charges in credit operations;

(2) Reimbursable, for technological development projects of companies, in the form of loans.

The absence of this information represents a deficiency of this database and, therefore, does not allow the separation of FNDCT resources by type of support –whether reimbursable or not. Reimbursable funds and loans will be computed in accordance with table 3, and should be considered as publicly-oriented resources, as, in this case, the funding is guided by public policies. Non-reimbursable funds are accounted for as public funding.

FINEP data

The Funding Authority for Studies and Projects (FINEP) plays the role of Executive Secretary to the FNDCT, as determined by Decree No. 68,748 of 15 June 1971, and ratified by Law No. 11,540 of 12 November 2007. As such, it is in charge of all FNDCT administrative, budgetary, financial, and accounting activities

(FINEP, 2019). FINEP provides reimbursable and non-reimbursable grants to Brazilian research institutions and companies. Its support covers all stages and dimensions of the science and technology development cycle: basic research, applied research, product innovation and development, services, and processes. FINEP also supports the incubation of technology-based companies; the establishment of technology parks; the structuring and consolidation of research processes; the development and innovation of established companies; and the development of markets. In addition, as of 2012, FINEP also started supporting the implementation of first industrial units, as well as mergers, acquisitions and joint ventures.

The FINEP database provides information on FINEP projects, as well as INOVACRED. This reimbursable funding line uses its own resources, as well as FNDCT funds. Its objective is to support Brazilian companies with annual gross operating revenue of up to R$ 90 million for the development of new products, processes, and services; or the improvement of existing ones; or marketing and innovation; or organizational innovation. It aims to boost competitiveness both at regional and national level.

The FINEP project database can be used for the EBP project as it contains the minimum information required for the classification of energy technologies, as discussed in Chapter III. The records include project title; name of executing agency; nature of funding (reimbursable or not); contracted amounts; and term of execution. However, some problems have also been identified: in non-reimbursable funds, there is no distinction between FNDCT funds (already computed through MCTI data) and other resources. Therefore, in order to avoid duplication, we have chosen to compute only reimbursable fund projects.

The database does not include any parameters that may be useful for classifying projects by technology area or sectoral fund. Besides, it only provides project titles, without a summary or other description that might allow a more precise use of search and classification terms according to energy categories, as proposed in the methodology of this project. In addition, applying search terms only to project titles increases the likelihood of errors in FINEP's energy investment amounts. As a result, we have selected only 32 energy projects out of a total of 1,991 projects. These projects account for approximately 3.5% of the amount of all reimbursable funds managed by FINEP from 2013 to 2018.

There were other difficulties related to identifying research and development projects, and demonstration projects. It was impossible to tell one from the other in most databases examined by the EBP team. The FINEP database, however, classifies these projects by support instrument, thus enabling the identification of publicly-oriented financing.

CNPq data

The National Council for Scientific and Technological Development (CNPq) in involved in a significant number of extra-FNDCT investments, with a considerable share in the energy area. Thus, we approached the CNPq Data and Information Coordination Team to request a cut-off from the investment database in energy areas, taking care to exclude projects financed by the FNDCT, as they are already registered in the FNDCT database provided by the MCTI. The non-FNDCT data were sent later, and computed only in the last stage of the project.

The data obtained from the CNPq were related to energy and covered the period from 2010 to 2019, including 18,741 research grants. The selected projects from 2013 to 2018 accounted for 12,284 scholarships. The available information on these grants was: "project title"; "year of implementation"; "beneficiary"; "support line" (type of grant and type of support); "level" (scientific initiation, master's, doctorate etc.); "call" and " programme "; " area of knowledge "; " institution of origin and destination"; "federative unit"; and "amount paid".

Although the available information on the area of knowledge was rather detailed, we selected the search terms because they are consistent with the classification of IEA technology categories

(Chapter II). In the CNPq selection, we found projects related to dietetics, nutrition, astronomy, biology, botany, pharmacy, physics, etc., probably because the title contained the word energy (they were later deleted manually). Thus, after applying the search terms to the field "project title", 5,944 research grants were classified, corresponding to 48% of the grants and 21.7% of the amounts contained in the database sent by CNPq for the period 2013–2018.

Another characteristic of this database is that any information on the grant period was restricted to the year of its implementation. Therefore, scholarships were assigned to a single year, as their whole implementation terms were not available in the database.

ANP data

The National Agency of Petroleum, Natural Gas and Biofuels (ANP) has two project databases. The first one, called RT5 Projects (ANP, 2019b), lists projects submitted by oil companies from 1998 to 2005, and projects submitted from 2005 to 2017, according to the rules of ANP Technical Regulation No. 05/2005. This resolution required less information on the projects. For this reason, the database does not meet the minimum information requirements, mainly because it does not contain project amounts.

The second database, called RT3 Projects (ANP, 2019a), contains the list of projects submitted by oil companies in accordance with the provisions of ANP Technical Regulation No. 03/2015. This database was collected on 29 October 2019 and is quite complete, meeting almost all our needs in terms of quantifying RD&D investments. However, this database has a much more limited time scope, as it only includes projects contracted between 2016 and 2019. ANP projects are split between these two databases, but only one of them has information on the contracted amount, and the other has complete data only for 2018.

While the RT5 project database included 268 projects for that year, the RT3 database contained 326 projects. Therefore, we have chosen to use the RT3 base for 2017 and 2018, noting that the numbers for 2017 are partial estimates of ANP projects for the year. A total of 933 projects were computed in the ANP database for the years 2016 to 2018. All those projects were considered in this study.

The project amounts calculated on the RT3 database correspond to the amounts obtained. These data are not necessarily the same as those provided by the companies, which, according to the ANP, are monitored after the completion of the projects. These amounts were prorated for project periods, which ranged from 3 to 60 months.

Although the RT3 database contains information on R&D activities carried out during the project, in addition to a classification of projects by energy technology, its use might send readers a wrong message. In this case, for complete data coverage over the period, a consultation was made with the ANP, which sent us the total amount of investments declared by the companies in the years 2013 to 2018. These figures were considered to be R&D investments in fossil fuel technologies (category 2 of this study).

In the case of biofuels and other energies, a first exercise indicated that these data referred to 2% to 3% of the investment. Therefore, in this case, we will consider that the total volume of projects declared by the ANP was destined for category-2 projects.

Regarding the nature of the expenses, ANP projects are considered as publicly oriented. Half the volume of investments must be made by STIs, and the other half can be either made by the company itself, or by third parties (STIs and/or other companies in the sector and/or suppliers) contracted to provide R&D services. The flows are for external contracting or internal R&D execution. As ANP R&D funds are subject to public regulation and supervision by that agency, such R&D investments are considered to be of public interest, which justifies their inclusion in this work.

ANEEL data

The Brazilian Electricity Regulatory Agency's R&D database is available on the agency's website, and the database used in this study (ANEEL, 2019a) was accessed on 29 October 2019. We used the database entitled "P&D da ANEEL" (ANEEL R&D), as it is quite complete and meets practically all the search requirements. The database includes a set of projects with contracting date starting in 2008, and extends until 2019. Thus, it meets the objectives of this study, i.e. measuring expenses from 2013 to 2018.

This database required special attention because it contained projects that had been cancelled. For this reason, it was first necessary to exclude all cancelled projects from the "Situação" (status) column. The remaining records were included in the statistics.

The project amounts correspond to the total expected amounts. Some projects provide information on the total executed amount. However, the data are scarce, and a large number of projects do not have this information, which makes them unfit for this study. This should only occur in the few cases where only the total executed amount is available. In addition, the total estimated amounts listed in the ANEEL database are equivalent to those of the ANP database, and refer to contracted amounts.

As in the ANP database, project amounts were prorated by the number of months, which varied from 1 to 60. As the maximum project length was 60 months, this study only considered projects starting between 2011 and 2018. Thus, for example, for projects started in 2011, only the amounts from 2013 onwards were computed.

The total number of ANEEL projects computed for the 2013–2018 period was 1,769. All these projects were classified according to the IEA's energy technology categories. The ANEEL database also contains columns that enable the classification of each project's energy technologies. The "Segmento" (segment) column presents the most aggregated classification using the following categories: commercialization, distribution, generation, and transmission. However, this classification is too aggregated to identify the main two-digit categories in the IEA classification. This can be done through the "Tema" (theme) column, which contains a long list of categories: Energy Efficiency, Alternative Sources, Generation, Generation/ Supervision, Control and Prototype, Thermal Power Generation, Management of Basins and Reservoirs, Measurement, Collection and Combat, Environment, Electric System Recovery, Electric System Planning, Service Quality and Reliability , Safety, Supervision, System Control and Protection, and Transmission. Although these correspond to IEA categories (e.g. Energy Efficiency), additional debugging work was required for this study.

In the case of renewable sources, including small and large hydroelectric plants, wind, solar, biogas, biomass, hydrogen, etc., we used search terms to identify the projects. We searched the columns named "Título" (title) and "Descrição do produto" (product description), as they provided detailed information on the projects.

Although in many cases we were able to use the ANEEL database, we also used our search terms to complete the classification of projects, as in the case of electric vehicles, coal, CO_2 storage, solar power, nuclear power, hydrogen, fuel cells, energy storage and energy systems.

The separation between energy company and executing entity is a hallmark of ANEEL's projects. Funding entities are companies in the electricity sector that need to invest a percentage of their net operating revenue: 1% in the case of energy generation and transmission companies, and 0.5% in the case of energy distributors (as they must also invest another 0.5% in energy efficiency). This percentage is distributed between 40% for the FNDCT, 40% for ANEEL-regulated R&D projects, and 20% for the MME/EPE (ANEEL, 2019a). According to data from the ANEEL's R&D Transparency Portal, since 2014 70% of project costs were performed by entities other than the companies themselves (ANEEL, 2019b).

The expenses incurred by ANEEL's R&D projects are classified in this study as publicly-oriented, as they derive from R&D investments funded by companies and performed by them or by external entities, such as STIs, other energy companies, or suppliers. When the same company is both the investor and the executor, the project can be considered as internal R&D execution. When it involves external R&D contracting, it is listed as R&D procurement.

BNDES data

The database of the National Bank for Economic and Social Development (BNDES) consists of a search conducted on the BNDES website. This database (BNDES, 2020) contains information on projects from 2002 to 2019. The information contained in this database is very extensive and meets this study's research criteria.

The database contains information on all funding granted by the BNDES. Its statistical unit is the funding provided to companies. The same project and entity may receive multiple funds. This database concerns both BNDES loans, reimbursable funding, and non-reimbursable funding. In this study, we have computed these flows together. However, they can be easily separated.

The time coverage of the database is very wide (2002 to 2019), and therefore meets the needs of this study. In order to identify projects included in our focus period, we had to mine projects from the period 2013 to 2018. Time-related data included the contract date, and the entire repayment period (including grace period and amortization period). Thus, the financed amount was prorated over that period of time.

As BNDES financing is not restricted to investments in RD&D, the first challenge was to separate these projects from the others. This was done using the "Inovação" (innovation) column. Only 914 operations corresponding to the period 2013–2019 responded affirmatively to this column, and were thus selected.

Information on project activities was found in the "Descrição do Projeto" (project description) column. We mainly used search terms to identify and classify projects by energy technology. In addition to search terms, we used the "CNAE Subsetor" (CNAE subsector) column, which contains a very detailed sector classification to identify funding for oil and gas and biofuels. Our subsectors of interest were: Sugar Cane Cultivation; Oil and Natural Gas Extraction; Manufacture of Machinery and Equipment for Petroleum and Natural Gas Prospecting and Extraction; Alcohol Production; Refined Vegetable Oils, except Corn Oil; and Manufacture of Seamless Steel and Tubes.

The executing entity can be identified in the "Cliente" (client) column. The vast majority of projects, which are reimbursable, were executed by companies. Only non-reimbursable projects were carried out by STIs.

FAPESP data

Given the representativeness of the state of São Paulo in the Brazilian innovation system, and of the São Paulo State Research Foundation (FAPESP) as a promoter of science, technology and innovation at state level, the FAPESP database was used to analyse public investments in energy in the state of São Paulo.

FAPESP funds investments in several energy areas through regular lines of credit and specific tenders. One the most outstanding programmes is BIOEN, launched in 2008. The FAPESP Bioenergy Research Programme (BIOEN) aims to stimulate and coordinate research and development activities, using academic and industrial laboratories to promote the advancement of knowledge and its application in areas related to the production of bioenergy in Brazil.

The FAPESP Virtual Library's webpage (2019) contains information on the projects funded by the institution. Based on this platform, a search was made on 23 August 2019 applying some broader search terms, in order to group the largest possible number of projects related to these subjects. A total of 1,968 records were found, including projects starting between 2011 and 2019, using the following terms: "Eficiência Energética" (energy efficiency), "Petróleo" (petroleum, or oil), "Gás" (gas), "Carvão" (coal), "Captura e Armazenamento de CO_2" (CO_2 capture and storage), "Fotovoltaica" (photovoltaic), "Geotérmica" (geothermal), "Eólica" (wind), "Biocombustíveis" (biofuels), "Ondas/Oceano" (waves/ocean), "Energia" (energy), "Bioenergia" (bioenergy), "Eletricidade" (electricity), "Fissão e Fusão Nuclear" (nuclear fission and fusion), and "Hidrogênio" (hydrogen). This database was treated to check for possible duplication of projects that may have been included in more than one search term, and to exclude those that were completed before or after the period of interest (2013–2018).

The FAPESP platform enabled us to gather most of the necessary information for the EBP, including a summary, which allowed us to apply search terms and classify projects according to energy categories. In addition to this, it also includes details on project title, beneficiary institution, partner institutions, funding line, area of knowledge, subject, and project start and end date. Regarding the funding line, it is possible to identify whether it is a scholarship, and what level (scientific initiation, master's or doctorate, post-doctorate or technical training), in addition to information on partnerships with national and foreign institutions, and in this case , the type of resource (e.g. a research grant).

However, as the disbursed amounts constitute confidential information, they are not disclosed on the website. In order to obtain that information, we made direct contact with FAPESP, and sent them a spreadsheet with the projects collected from their virtual library platform. FAPESP granted our request and added details on the amounts disbursed for each project.

Brazilian Nuclear Programme data

Our search included investments aimed at the Brazilian Nuclear Programme. These data were obtained from the federal budget, available on the SIGA Brasil system (Senado Federal, 2019). Data on federal public investments made available by the Ministry of Science, Technology and Innovations (MCTI) show that there is a significant amount of investments made by the Nuclear Energy Commission (CNEN), associated with the MCTI.

For this reason, a more detailed analysis of the federal budget was carried out on the SIGA Brasil system (Senado Federal, 2019) to identify MCTI nuclear policy programmes. We found a programme named 2059 – Brazilian Nuclear Policy. The method recommended by Hollanda (2003) to identify RD&D spending is at the level of government action. It should be noted that data with the required level of detail is only available until 2017.

We identified the funds paid from 2013 to 2018 for budgetary actions that are more in line with the concept of Nuclear Research and Development under the 2059 Programme. The figures included actions aimed at supporting RD&D through international cooperation, the implementation of the Brazilian multipurpose reactor, the implementation of a nuclear fusion laboratory, and specialized training for the nuclear sector. We avoided duplication with FNDCT data channelled to the nuclear programme by deducting the FNDCT amounts invested in Brazilian Nuclear Policy.

VI. Data consolidation and limitations

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

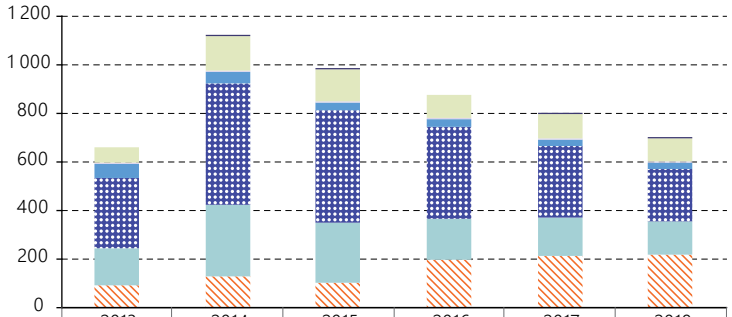
Public investments in energy RD&D

This section provides an overview of energy RD&D investments with resources coming exclusively from public sources. It was based on data provided by the following institutions: 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); the National Bank for Economic and Social Development (BNDES); the National Nuclear Energy Commission (CNEN); the São Paulo State Research Foundation (FAPESP); and SIGA Brasil.

Figure 1 shows the sum of public investments in energy research, development and demonstration by technology category (digit 1, as per table 1; thousands of Brazilian reals, 2018 prices). Most public investments in RD&D are focused on renewable energy technologies, followed by fossil fuels, energy efficiency and other power and storage technologies.

The total amount of public investment in energy RD&D has seen a downward trend since 2015, after peaking in 2014 with over R$ 1 billion (in 2018 values). This decline is partly due to a significant budget sequestration imposed on the FNDCT, one of the main sources of RD&D funding in Brazil, as well as the economic crisis that the country has faced in recent years.

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

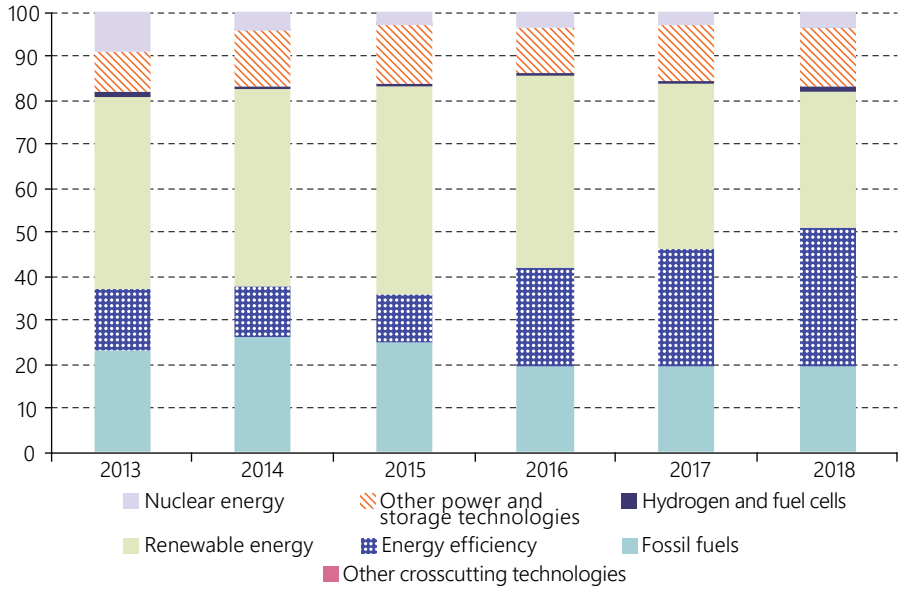


	2013	2014	2015	2016	2017	2018
Other cross-cutting technologies	0.00	0.03	0.04	0.00	0.01	0.01
Other power and storage technologies	60.24	140.97	131.23	89.51	100.84	95.53
Hydrogen and fuel cells	4.98	5.51	6.31	6.37	5.26	6.13
Nuclear energy	59.89	47.56	30.28	31.20	23.87	23.68
Renewable energy	290.36	502.02	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.

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 importance compared to the 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 2.

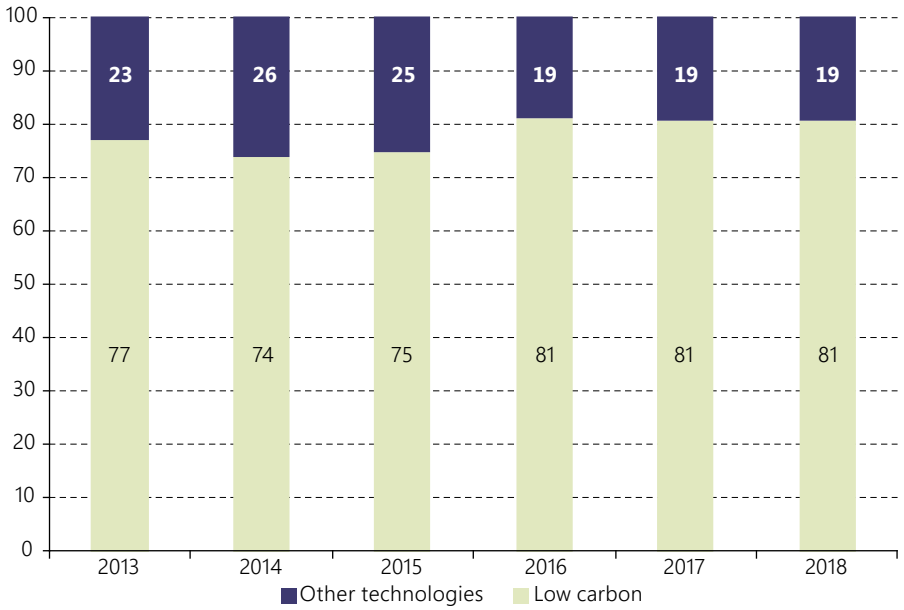
Figure 2
Shares of energy categories in public expenditure on energy RD&D per year
(Percentages)



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

Figure 3 shows a percentage comparison between RD&D projects focused on low carbon technologies[3] and other technologies[4]. 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.

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



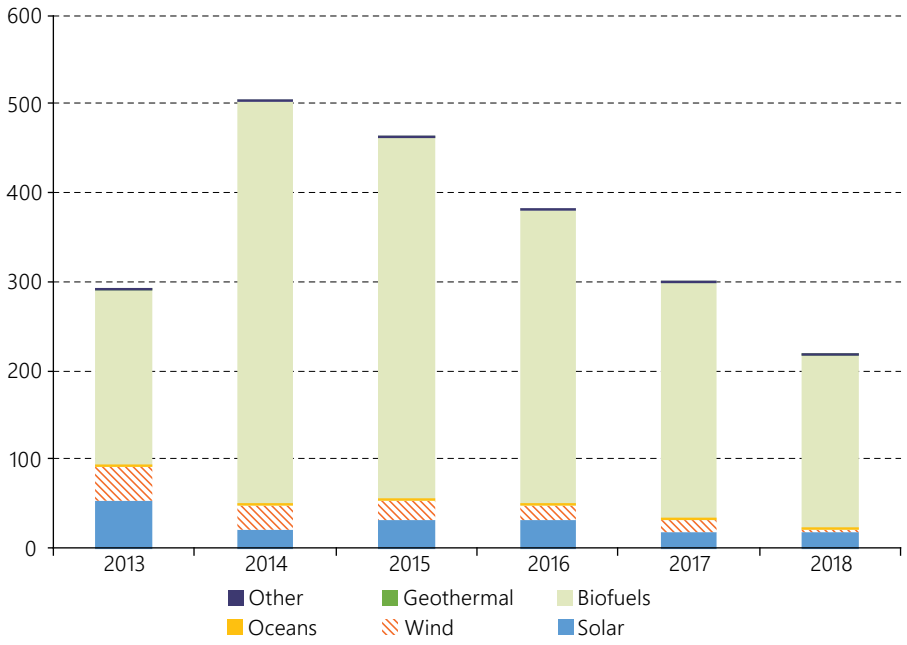
Source: Created by the authors based on data from MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and SIGA Brasil.

Figure 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 amount of investments. The fact that Brazil has a very strong biofuels sector, and that the country's Nationally Determined Contribution (NDC) includes a commitment to increasing the share of biofuels in its energy mix by 2030 (Brasil, 2015), is consistent with the amount of public RD&D investments aimed at this sector. However, reflecting on the amounts destined for research, development and demonstration in other renewable technologies (solar, wind, oceans, hydroelectricity and geothermal), the latter are marginal when compared to those destined for biofuel RD&D.

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. Efforts towards resuming 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 grow from 17% to 23% in the transport mix, and wind and solar power to reach 8% of the domestic supply of electricity, with respectively 15 GW and 2.4 GW installed capacity (EPE, 2019).

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

Figure 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.

Publicly-oriented investments in energy RD&D

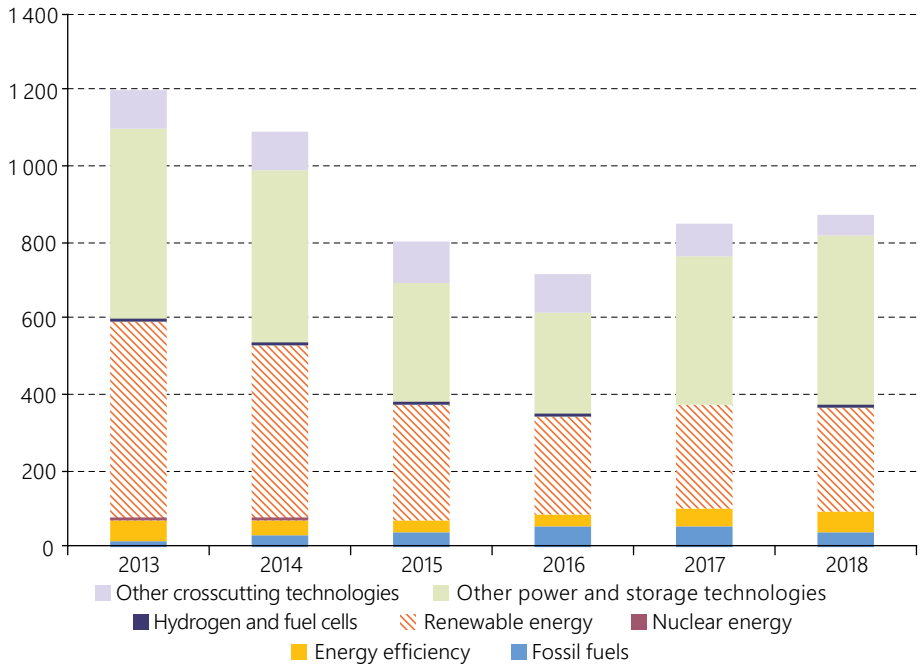
The estimate of publicly-oriented investments found through this study provides an overview of these investments in energy RD&D according to the classification adopted by the IEA. Publicly-oriented investments are regulated by the Brazilian Electricity Regulatory Agency (ANEEL) and the National Agency for Petroleum, Natural Gas and Biofuels (ANP), and our analysis was based on public data available on these agencies' websites.

R&D programme regulated by ANEEL

Figure 5 shows the sum of publicly-oriented investments in energy research, development and demonstration regulated by ANEEL by energy technology category (as per table 1).

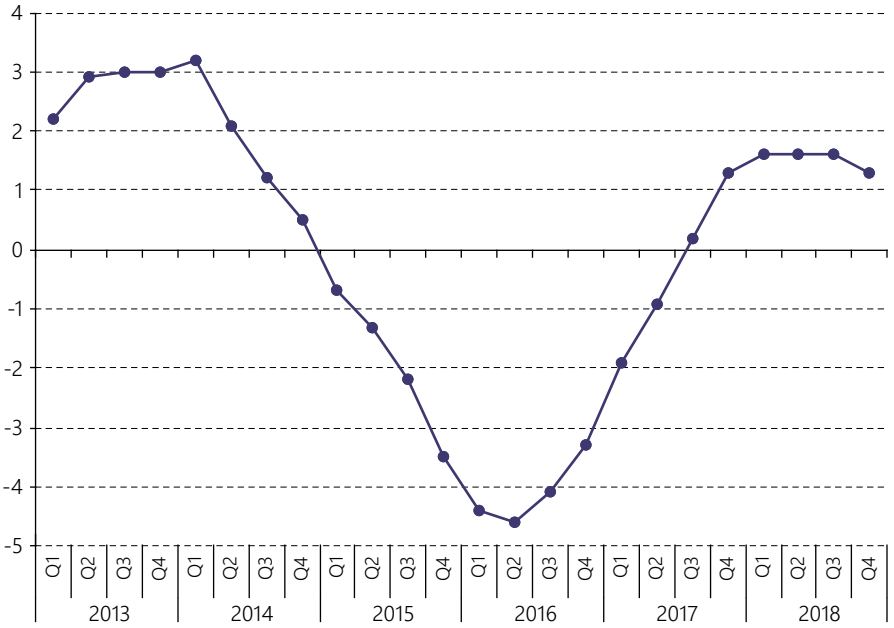
Most of the investments in RD&D made under the ANEEL programme are focused on renewable energy technologies and other energy generation and storage technologies. As R&D funds are linked to the annual turnover of companies in the sector, the U-curve shown in the chart reflects the crisis and economic retraction that the country went through from 2103 to 2016, as well as the beginning of its recovery in 2017, which raised turnover in the sector and, consequently, increased investments in R&D. This curve is very similar to the Brazilian Gross Domestic Product (GDP) curve for the same period, as can be seen in figure 6.

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

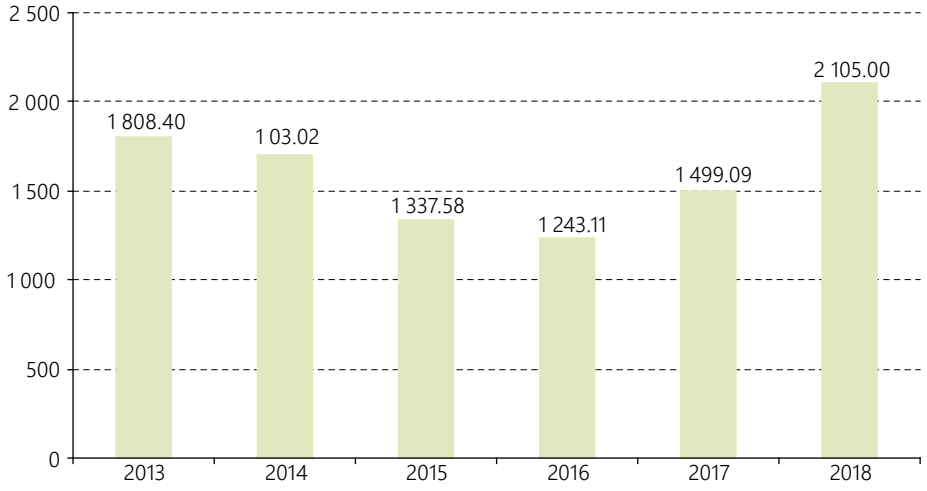


Source: Created by the authors based on Brazilian Institute of Geography and Statistics (IBGE), "Sistema de Contas Nacionais Trimestrais" [online] https://www.ibge.gov.br/estatisticas/economicas/contas-nacionais/9300-contas-nacionais-trimestrais.html [Accessed on 30 April 2020], 2020.

R&D programme regulated by the ANP

As explained in Chapter V, although the ANP website allows users to download spreadsheets with data on ANP-regulated R&D projects, the parameters contained in these databases did not meet the essential requirements for applying our classification method through the use of search terms. Thus, we asked the ANP directly for the values of its energy projects during the period of analysis of the study. These data were made available in aggregate form. With only aggregated data, we adopted the assumption that all ANP-regulated investments focused on fossil fuels. 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 7 shows the evolution of expenditures made for ANP-regulated R&D projects.

Figure 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.

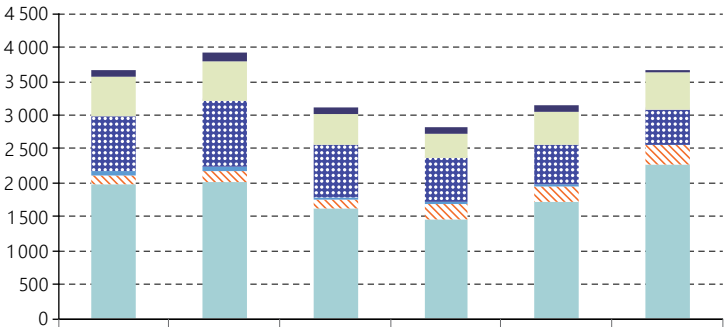
Once again, a U-shaped curve illustrates the total volume of R&D expenditures, which is also similar to the GDP curve for the period, consistent with the fact that the research, development and innovation clause (RD&I clause, as described in Chapter I) in contracts for oil and gas exploration, development and production 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 in the sector in 2018, increasing the volume of regulated RD&D activities.

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 National Nuclear Energy Commission – CNEN).

Figure 8 shows the sum of public and publicly-oriented investments in research, development and demonstration by energy technology category (as per table 1) from 2013 to 2018.

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



	2013	2014	2015	2016	2017	2018
Other cross-cutting technologies	103.74	98.73	110.74	100.36	87.31	53.42
Other power and storage technologies	563.63	597.93	446.41	362.26	490.99	541.79
Hydrogen and fuel cells	9.19	7.39	8.46	7.82	5.26	7.03
Renewable energy	807.32	966.44	765.53	636.94	571.58	488.60
Nuclear energy	61.29	48.54	30.28	31.20	23.87	23.68
Energy efficiency	140.84	160.88	135.68	231.62	256.14	274.59
Fossil fuels	1 978.84	2 027.21	1 620.53	1 461.75	1 707.18	2 279.24

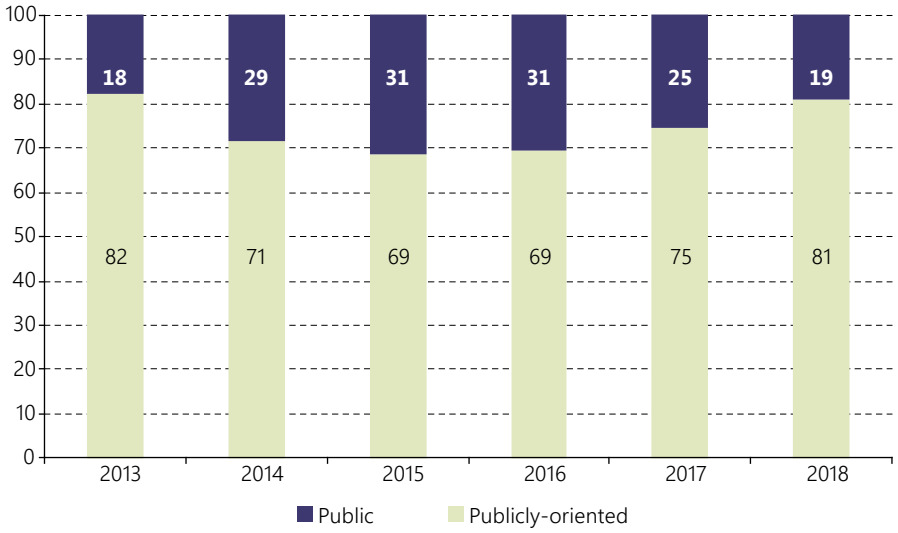
Source: Created by the authors based on data from ANEEL, ANP, MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and SIGA Brasil.

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 investment obligations of businesses in the oil and gas sector, regulated by the ANP (as seen earlier in Chapter VI).

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

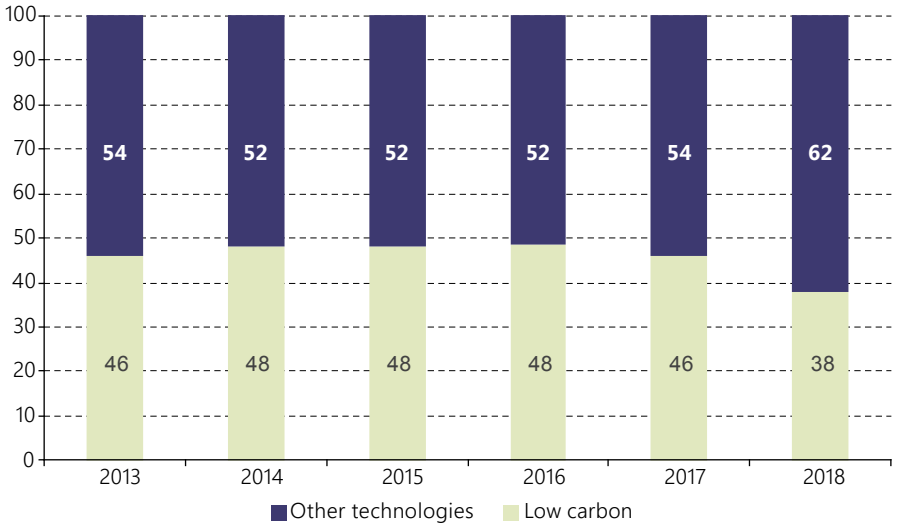
Figure 10 shows a percentage comparison between public and publicly-oriented investments in RD&D projects aimed at low-carbon technologies and other technologies. The higher percentage share of *Other Technologies* is due to the weight of investments in ANP-regulated projects, classified under category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

Figure 9
Share of public and publicly-oriented expenditures in 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.

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

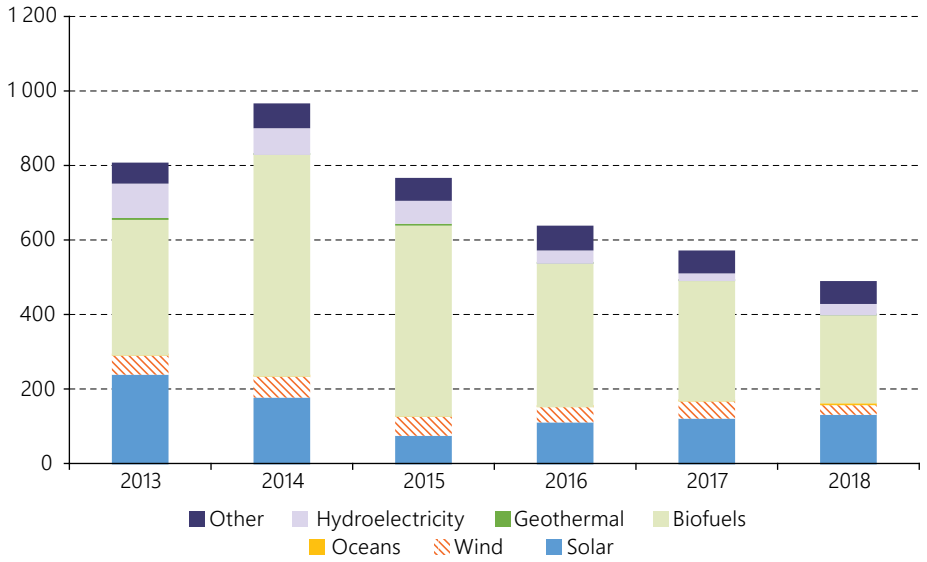


Source: Created by the authors based on data from ANEEL, ANP, MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and SIGA Brasil.

It is important to note that, although all ANP projects were classified as Other Technologies (not low-carbon), it is a fact that part of these investments may be destined to projects in other 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 ought to be undertaken to obtain a clearer understanding of the share of such investments.

Figure 11 shows the evolution of public and publicly-oriented investments in renewable energy RD&D between 2013 and 2018. Biofuel RD&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.

Figure 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 ANEEL, ANP, MCTI/FNDCT, FINEP, CNPq, BNDES, FAPESP and SIGA Brasil.

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 research and development of new ideas and emerging technologies, since they need coordinated and constant investments in all stages of their development, from basic research to commercialization.

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, the overview presented in this study, 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.

Limitations

This study has important limitations. The first is that it was not possible to separate funding entities from executing entities. Although this information was available in some of the databases, coverage was incomplete, making such classification impossible. As we said earlier in this report, RD&D figures are related to funding sources.

The second important limitation is that it was not possible to separate research and development from demonstration. It was noted that some of the projects reported in the BNDES, ANP and ANEEL databases may be related to the demonstration stage. However, it is necessary to validate this information with the institutions responsible for it before reaching any conclusions.

A third important constraint regarding these figures is the incomplete coverage of federal and state public funding. Federal government data still do not correspond to the total energy-related RD&D expenditures. A significant share of federal R&D expenditures is made through the Ministry of Education, which is estimated to be responsible for about 60% of all federal R&D expenditures in Brazil (MCTI, 2019c). Due to the large volume of information, and the consequent difficulty in identifying the type of research carried out, dividing these data by energy technology is a complex task. However, it is important to take a broader view, as a significant share of Brazilian graduate programmes operate in the energy area. The same applies to Treasury expenses at state universities. It is important to note that the IEA includes RD&D expenses for basic and applied research, where investments in graduation programmes should be accounted for. The expenses incurred by other federal government departments, which concentrate large R&D investments, were not included in this research. The Ministry of Agriculture, for example, accounted for 12% of all federal investment in R&D in Brazil in 2016 (MCTI, 2019c).

Another major limitation concerns state-owned enterprises. Both Petrobras and Eletrobras are important policy actors in the Brazilian energy sector. However, investments made through CENPES and CEPEL (respectively Petrobras' and Eletrobras' research centres), as well as their subsidiaries, outside the context of ANP and ANEEL projects, were not quantified at this stage.

Expenses made at state level —other than São Paulo— were not collected and estimated, neither by state research support foundations nor by the state postgraduate system. Furthermore, there is no estimate on these companies RD&D investments made outside the scope of public reimbursable funding and ANP's and ANEEL's contractual R&D obligations.

VII. Next steps

In order to improve the analysis of energy RD&D investments in Brazil, and aiming to produce more robust results, some challenges should be overcome. We propose, therefore, that the following activities be carried out in subsequent stages of this work:

- 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;
- 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;
- Completing the missing information on ANP-regulated RD&D projects, which may enable a more accurate classification of investments according to IEA categories;
- Adding data from other federal organizations, especially the Ministry of Education and the Ministry of Agriculture;
- Mapping data at state level and by state-owned enterprises, and exploring methodological alternatives for surveying RD&D expenditures and refining their classification;
- Reaching an agreement among all entities involved to ensure a regular flow of information;
- 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;
- 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;
- 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 on the 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;

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

Bibliography

ANEEL (Agência Nacional de Energia Elétrica) (2019a), "Programa de Pesquisa e Desenvolvimento Tecnológico do Setor de Energia Elétrica" [online] https://www.aneel.gov.br/programa-de-p-d [Accessed on 2 September 2019].

_____(2019b), "Transparência, entidades beneficiárias" [online] https://www.aneel.gov.br/programa-de-p-d [Accessed on 2 September 2019].

ANP (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (2020), "Projetos de PD&I" [online] http://www.anp.gov.br/pesquisa-desenvolvimento-e-inovacao/investimentos-em-p-d-i/projetos-de-pd-i [Accessed on 13 September 2019].

_____(2019a), "Projetos RT3" [online] http://www.anp.gov.br/arquivos/pdi/ipd&i/projetos-rt3-2015.xlsx [Accessed on 13 September 2019].

_____(2019b), "Projetos RT5" [online] http://www.anp.gov.br/arquivos/pdi/investimentos-pdi/projetos-rt5-2005.xlsx [Accessed on 13 September 2019].

_____(2019c), "Regulação técnica de PD&I" [online] www.anp.gov.br/pesquisa-desenvolvimento-e-inovacao/investimentos-em-p-d-i/regulamentacao-tecnica-relativa-aos-investimentos-em-p-d-i [Accessed on 29 April 2020].

BNDES (Banco Nacional do Desenvolvimento Econômico e Social) (2020), "Principais projetos financiados" [online]https://www.bndes.gov.br/wps/portal/site/home/transparencia/consulta-operacoes-bndes/consulta-op-dir-ind-nao-aut [Accessed on 30 June 2019].

Brasil, República Federativa do (2015), *Pretendida Contribuição Nacionalmente Determinada para Consecução do Objetivo da Convenção-Quadro das Nações Unidas sobre Mudança do Clima*, Brasília, Ministério das Relações Exteriores.

CGEE (Centro de Gestão e Estudos Estratégicos) (2017), "Desenho e detalhamento do primeiro nível do metaprocesso Inteligência Estratégica em CTI", *Documento preparado para o Projeto Modelagem e Automação de Processos Finalísticos*, Centro de Gestão e Estudos Estratégicos, Ministério da Ciência, Tecnologia e Inovação e Comunicações, Brasília, December.

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

EPE (Empresa de Pesquisa Energética) (2019), *Balanço Energético Nacional*, Rio de Janeiro, MME, May.

FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) (2014), "Dispêndios em P&D em São Paulo atingiram R$ 21,8 bilhões em 2011 e parcela do PIB chegou a 1,61%. No Brasil, somaram R$ 47,2 bilhões, ou 1,14% do PIB" *Indicadores FAPESP de Ciência, Tecnologia e Inovação*, Boletim no. 4, May.

_____(2019), "Biblioteca Virtual FAPESP" [online] https://bv.fapesp.br/ [Accessed on 30 June 2019].
FINEP (Financiadora de Estudos e Projetos) (2019), "Composição do FNDCT" [online] http://www.FINEP.gov.br/a-FINEP-externo/fndct/estrutura-orcamentaria/composicao-do-fndct [Accessed on 30 August 2019].
Hollanda, Sandra (2003), "Dispêndios em C&T e P&D", *Indicadores de Ciência, Tecnologia e Inovação no Brasil*, Viotti, Eduardo Baumgratz and Mariano de Matos Macedo (org.) Campinas, Editora da Unicamp.
IEA (International Energy Agency) (2011), *IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics*, IEA/OCDE, Paris, June.
_____(2015) *Questionnaire for in-depth energy policy reviews 2015–16 cycle*, IEA/OCDE, Paris, June.
MCTI (Ministério da Ciência, Tecnologia e Inovações) (2019a), "Recursos Aplicados–Indicadores Consolidados" [online] https://www.mctic.gov.br/mctic/opencms/indicadores/detalhe /recursos_aplicados/indicadores_consolidados/2_1_2.html [Accessed on 29 April 2020].
_____(2019b). "Tabela 2.2.3 Brasil: Dispêndios do governo federal em ciência e tecnologia (C&T), aplicados pelo Ministério da Ciência, Tecnologia e Inovação (MCTI), por unidade orçamentária e atividade, 2000–2016." [online] https://www.mctic.gov.br/mctic/opencms/indicadores/detalhe/ recursos_aplicados/governo_federal/2_2_3.html [Accessed on 2 September 2019].
_____(2019c) "Tabela 2.2.2 Brasil: Dispêndios do governo federal em ciência e tecnologia (C&T) (1) (2) por órgão, 2000–2016." [online] https://www.mctic.gov.br/mctic/opencms/indicadores/detalhe/recursos_aplicados/governo_federal/2_2_2.html [Accessed on 2 September 2019].
OECD (Organisation for Economic Co-operation and Development) (2015), "Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development", *The Measurement of Scientific, Technological and Innovation Activities*, OECD Publishing, Paris.
Pacheco, Carlos (2018), "O FNDCT e a Reforma do Financiamento de CT&I" [online] http://legis.senado.leg.br/sdleg-getter/documento/download/ebf9627c-745f-4afc-924f-7ddfaodb17dc [Accessed on 16 December 2019].
Petrobrás (Petróleo Brasileiro S.A) (2019), "Form 20 F" [online] https://www.investidorpetrobras.com.br/pt/resultados-e-comunicados/relatorios-anuais [Accessed on 2 September 2019].
Senado Federal (2019), "Portal do Orçamento, SIGA Brasil Relatórios" [online database] https://www12.senado.leg.br/orcamento/sigabrasil [Accessed on 6 September 2019].
UN (United Nations) (2015), *Transforming our World:* The 2030 Agenda for Sustainable Development (A/ RES/70/1), New York, United Nations Publication.

Annexes

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Annex 7
Protocols

ANEEL Protocol

Protocol for the ANEEL database

Sequence of actions:

(1) Open file "ANEEL P&D.xlsx";

(2) Save "Plan1" tab as an independent file with a ".csv" extension, and name it "ANEEL.csv";

(3) Import "ANEEL.csv";

(4) Import "5.PD RF EQUIPE.csv";

(5) Merge projects in order to incorporate the "Entidade_Vinculada" (linked entity) variable into the ANEEL database;

(6) Create identifier code for projects in the database;

(7) Apply filter: select projects whose "Ano de Utilização" (year of use) is greater than or equal to 2013;

(8) Define search terms associated with the IEA category (Expert Task);

(9) Change text from the "Título" (title) variable to lowercase;

(10) Change text from the "Segmento" (segment) variable to lowercase;

(11) Change text from the "Tema" (theme) variable to lowercase;

(12) Change text from the "Descrição do Produto" (product description) variable to lowercase;

(13) Apply search terms;

  (a) Perform search on variables "Título" (title), "Segmento" (segment), "Tema" (theme), "Descrição do Produto" (product description), "Subtema" (sub-theme) using category 1.1 terms;

  (b) Create a vector that points to 1 when the term is recognized in any of the search variables, and 0, otherwise;

  (c) Repeat (a) and (b) for other available categories;

  (d) Create a project-category matrix;

(14) Group the project-category matrix into the database;

(15) Calculate the contract length in months "Duração_Realizada_(meses)" (executed length [months]):

  (a) Start date is defined as loading date;

  (b) Projects starting and ending in the same month receive a value of 1;

(16) Calculate total cost estimated in 2013, observing the project's start date and end date (values are distributed uniformly throughout the length of the project);

(17) Repeat previous step for years 2014 to 2019;

(18) Create the sum vector for the total estimated cost for from 2013 to 2019 ("Custo_Total_ Previsto _2013.2019");

(19) Create an intermediate file to check the compliance of searches ("ANEEL_interm.csv");

(20) Analyse project conformity (Expert Task);

(21) Import corrected project-category matrix ("projeto-categoria");

(22) Create IEA category ("categoria IEA") vectors with 1 and 2 digits associated with the project (Categoria_dig1 and Categoria_dig2);

(23) Filter only projects that have been allocated to at least one of the categories;

(24) Assemble standardized spreadsheet for the ANEEL database:

  (a) Item = CodProj;

  (b) Fonte_de_dados (data source) = "Aneel";

  (c) Data_Assinatura (signature date) = Data_Início (start date);

  (d) Data_Limite (deadline) = Prazo_Utilização (term of use);

  (e) Duração_meses (length in months) = Duração_Realizada_(meses) (executed length [months]);

  (f) Custo_Total_Previsto (total projected cost) = Custo_Total_Previsto (total projected cost);

  (g) Cost_Total_Previsto_2013.2019 (total projected cost 2013–2019) = Cost_Total_Previsto _2013.2019 (total projected cost 2013–2019);

  (h) Nome_do_agente_financiador (name of funding agent) = ??;

  (i) Natureza_do_financiamento (nature of funding) = ??;

  (j) Modalidade _do_financiamento (type of funding) = ??;

(k) Nome_do_agente_Executor (name of executing agent) = ??;

(l) Natureza_do_agente_Executor (nature of executing agent) = ??;

(m)Categoria_da_tecnologia_digito1 (digit-1 technology category) = categoria_dig1;

(n) Categoria_da_tecnologia_digito2 (digit-2 technology category) = categoria_dig2;

(o) P&D_ou_Demonstração (R&D or demonstration) = ??;

(p) Custo_Total_Previsto _2013 (total projected cost 2013) = Custo_Total_Previsto _2013 (total projected cost 2013);

(q) ...;

(r) Custo_Total_Previsto _2019 (total projected cost 2019)= Custo_Total_Previsto _2019 (total projected cost 2019);

(25) Create "final_ANEEL.xslx" file based on standardized spreadsheet.

ANP Protocol

(1) Request data on RD&D projects declared by companies to the ANP;

(2) Calculate the disbursement made considering that projects were performed over a period of 5 years;

(3) Assemble spreadsheet with data on aggregate investments made with disbursement from the budget year by year.

BNDES Protocol

Protocol for the BNDES database

Sequence of actions:

(1) Open file "BASE_CONTRATAÇÕES_BNDES_TRANSPARENTE_30062019.xlsx";

(2) Save "Site" tab as an independent file with a ".csv" extension, and name it "BNDES.csv";

(3) Import "BNDES.csv";

(4) Create identifier code for projects in the database;

(5) Apply filter: select projects whose "Ano de Utilização" (year of use) is greater than or equal to 2013;

(6) Apply filter: Innovation equals "SIM" (yes);

(7) Define search terms associated with the IEA category (Expert Task);

(8) Change text from the "Descrição do Projeto" (project description) variable to lowercase;

(9) Apply search terms:

(a) Perform search on "Descrição do projeto" (project description) variable using category 1.1 terms;

(b) Create a vector that points to 1 when the term is recognized in any of the search variables, and 0, otherwise;

(c) Repeat (a) and (b) for other available categories;

(d) Create a project-category matrix;

(10) Group the project-category matrix into the database;

(11) Calculate the contract length in months "Prazo de Execução_(meses)" (length of execution [months]):

(a) Grace and financing periods were added to define the execution deadline;

(b) Projects starting and ending in the same month receive a value of 1;

(12) Calculate the contracted amount per year. Note date of signature and date of completion of the project (when not available, the date of completion is calculated based on the execution deadline):

  (a) The contracted amount is distributed evenly throughout the length of the project;

(13) Repeat previous step for the period of interest (2013 to 2019);

(14) Add values of each year to arrive at total contracted amount allocated for the period from 2013 to 2019 ("Valor_Contratado_2013.2019");

(15) Create an intermediate file to check the compliance of searches ("BNDES_interm.csv");

(16) Analyse project conformity (Expert Activity);

(17) Import corrected project-category matrix ("projeto-categoria");

(18) Create IEA category ("categoria IEA") vectors with 1 and 2 digits associated with the project (Categoria_dig1 and Categoria_dig2);

(19) Filter only projects that have been allocated to at least one of the categories;

(20) Assemble standardized spreadsheet for the BNDES database:

  (a) Item = Número_do_contrato;

  (b) Fonte_de_dados (data source) = "BNDES";

  (c) Data_Assinatura (signature date) = Data_da Contratação (contract date);

  (d) Data_Limite (deadline) = Prazo_Utilização (term of use);

  (e) Duração_meses (length in months) = Duração_Realizada_(meses) (executed length [months]);

  (f) Valor_contratado (contracted amount) = Valor_Contratado__R$ (contracted amount in R$);

  (g) Valor_Contratado_2013.2019(contracted amount 2013.2019)=Valor_Contratado__2013.2019 (contracted amount 2013–2019);

  (h) Nome_do_agente_financiador (name of funding agent) = ??;

  (i) Natureza_do_financiamento (nature of funding) = ??;

  (j) Modalidade _do_financiamento (type of funding) = ??;

  (k) Nome_do_agente_Executor (name of executing agent) = ??;

  (l) Natureza_do_agente_Executor (nature of executing agent) = ??;

  (m) Categoria_da_tecnologia_digito1 (digit-1 technology category) = categoria_dig1;

  (n) Categoria_da_tecnologia_digito2 (digit-2 technology category) = categoria_dig2;

  (o) P&D_ou_Demonstração (R&D or demonstration) = ??;

  (p) Valor_Contratado_2013 (contracted amount in 2013) = Valor_Contratado_2013 (contracted amount in 2013);

  (q) ...;

  (r) Valor_Contratado_2019 (contracted amount in 2019) = Valor_Contratado_2019 (contracted amount in 2019);

(21) Create "final_BNDES.xslx" file based on standardized spreadsheet.

FAPESP Protocol

Protocol for the FAPESP database

Sequence of actions:

(1) Access virtual library database on the FAPESP website <https://bv.fapesp.br/pt/>;

(2) Click on the "busca avançada" (advanced search) icon, and enter search terms, for example:

(a) "Eficiência" and "energética" (energy and efficiency);

(b) Select the period of interest: ENTRE 2010 E 2019 (between 2010 and 2019);

(c) Index, keep "todos" (all) for all fields;

(d) Click on search;

(e) Click on "exportar excel (CSV)" (export Excel [CSV]);

(f) Insert email to receive the spreadsheet;

(g) Repeat procedure for all search terms;

(3) Open the informed email, download and open the spreadsheets in Excel;

(4) Create a new Excel file and copy the spreadsheet for each search term to a tab in the new spreadsheet;

(5) Insert a column entitled "valor desembolsado" (disbursed amount) in column W in all tabs (after project term), with data to be inserted by FAPESP;

(6) Filter projects in all tabs according to the period:

(a) List in ascending order according to "data de término" (end date) column;

(b) Exclude projects with end date until 2012;

(c) List in descending order according to "data de início" (start date) column;

(d) Exclude projects with a starting date from 2019;

(7) Filter projects by knowledge area:

(a) List in ascending order according to "área do conhecimento" (knowledge area) column;

(b) Exclude projects in areas not related to energy, such as "saúde humana e animal, medicina, zoologia, ecologia, entre outros" (human and animal health, medicine, zoology, ecology, among others) that may have been selected by the FAPESP virtual library system;

(8) Exclude projects related to conferences, symposia, references and other science events:

(a) Filter projects by the "títulos" (titles) column, then manually check line by line, and delete them;

(b) Repeat procedure for all tabs in the spreadsheet;

(9) The last filtering occurs by simultaneously checking the "título" and "assunto" (title and subject) columns:

(a) Manually check the projects that do not correspond to the energy areas explicitly identified in these fields;

(b) For example, projects referring to energy from human and animal cells were identified in basic searches not related to the project's theme;

(10) Create a column in each tab entitled "categoria de busca vinculada na BV" (search category linked in BV) and add in all lines the search term used as a reference on the website of FAPESP's virtual library;

(11) Generate a blank file called "planilha unificada" (unified spreadsheet), then copy the spreadsheet of each tab to this new file, in sequence, creating a tab with all unified data;

(12) Send the unified spreadsheet to FAPESP, which, using the project identification number (first column), will include the amount disbursed in the corresponding column;

(13) FAPESP has provided data aggregated by energy class per year between 2005 and 2019. The data were then transferred to IEA categories.

CNPq Protocol

Protocol for the CNPq database

Sequence of actions:

(1) Open file "8.energia_cnpq_2010_2019.xlsx";

(2) Save "Exportar" (export) tab as independent file with extension ".csv" and named "8.energia_ cnpq_2010_2019.csv";

(3) Import "8.energia_cnpq_2010_2019.csv";

(4) Apply filter: select projects whose "Ano de Referência" (year of reference) is greater than or equal to 2013;

(5) Change database so that the notes become different projects, abandoning the format in which the notes (lines) refer to payments associated with the projects:

  (a) Create variables "Valor_2013" (value 2013), "Valor_2014" (value 2014), ... , "Valor, 2019" (value 2019);

  (b) Assign the amount spent in the reference year to respective variable "Valor_ANO" (value year);

  (c) Delete repeated lines;

(6) Define search terms associated with the IEA category (Expert);

(7) Change text from the "Título do Projeto" (project title) variable to lowercase;

(8) Apply search terms:

  (a) Perform search on "Título do Projeto" (project title) variable using terms from category 1.1;

  (b) Create a vector that points to 1 when the term is recognized in the search variable, and 0, otherwise;

  (c) Repeat (a) and (b) for the other available categories;

  (d) Create a project-category matrix;

(9) Group the project-category matrix into the database;

(10) The CNPq database does not have reference dates that enable the calculation of project execution time, so the values were attributed in their entirety to the reference year;

(11) Create vector of total amount paid for the period from 2013 to 2019 ("Valor_Pago_2013.2019");

(12) Create an intermediate file to check the compliance of searches ("CNPq_interm.csv");

(13) Analyse compliance of project allocation to categories (Expert);

(14) Filter only projects that have been allocated to at least one of the categories;

(15) Create project identification variable:

  (a) Paste "CNPq" into the process variable;

(16) Assemble standardized spreadsheet for the CNPq database:

  (a) Item = Cod_proj;

  (b) Fonte_de_dados (data source) = "CNPq";

  (c) Data_Assinatura (signature date) = " ";

  (d) Data_Limite (deadline) = " ";

  (e) Duração_meses (length month) = " ";

  (f) Valor_contratado (contracted amount) = " ";

  (g) Valor_Pago (paid amount) = Valor_Pago__2013.2019 (amount paid 2013–2019);

  (h) Nome_do_agente_financiador (name of funding agent) = ;

(i) Natureza_do_financiamento (nature of funding) = ;

(j) Modalidade _do_financiamento (type of funding) = ;

(k) Nome_do_agente_Executor (name of executing agent) = ;

(l) Natureza_do_agente_Executor (nature of executing agent) = ;

(m) Categoria_da_tecnologia_digito1 (digit-1 technology category) = categoria_dig1;

(n) Categoria_da_tecnologia_digito2 (digit-2 technology category) = categoria_dig2;

(o) P&D_ou_Demonstração (R&D or demonstration) = ;

(p) Valor_Pago_2013 (paid amount in 2013) = Valor_Pago_2013 (amount paid in 2013);

(q) ...;

(r) Valor_Pago_2019 (paid amount in 2019) = Valor_Pago_2019 (amount paid in 2019);

(17) Create "final_CNPq.xslx" file based on standardized spreadsheet.

FINEP Protocol

Protocol for the FINEP database

Sequence of actions:

(1) Open file "08_07_2019_Liberacoes.ods";

(2) Save "Projetos Finep" (FINEP projects) tab as an independent file with a ".csv" extension, and name it "FINEP.csv";

(3) Read file "FINEP.csv" disregarding the first five lines;

(4) Create identifier code for projects in the database;

(5) Apply filter: select projects whose "Prazo Utilização" (term of use) is greater than or equal to the date of 01/01/2013;

(6) Apply filter: select projects whose "Instrumento" (instrument) is equal to "Não reembolsável" (non-reimbursable);

(7) Define search terms associated with the IEA category (Expert);

(8) Change text from the "Título" (title) variable to lowercase;

(9) Apply search terms:

(a) Perform search on "Título" (title) variable using terms from category 1.1;

(b) Create a vector that points to 1 when the term is recognized in the search variable, and 0, otherwise;

(c) Repeat (a) and (b) for the other available categories;

(d) Create a project-category matrix;

(10) Group the project-category matrix into the database;

(11) Calculate the contract length ("período_meses");

(12) Add "valores liberados" (released amounts) under the same contract based on "Contrato" (contract) identifier;

(13) Calculate the amount released in 2013, observing project signature and project completion dates; (The spreadsheet includes Valor FINEP [FINEP value] and Valor Liberado [released value]. The former appears to be the contracted amount, while the latter appears to be the amount released. The point is that I cannot confirm this information, and given that the values under Valor_Finep are repeated exactly for various entries in the same project, their sum can lead to an overestimation of the real project value.);

(14) Repeat previous step for years 2014 to 2019;

(15) Create vector of total amount released for the period from 2013 to 2019 ("Valor_Liberado _2013.2019");

(16) Create an intermediate file to check the compliance of searches ("FINEP_interm.csv");

(17) Analyse project conformity (Expert);

(18) Import corrected project-category matrix ("projeto-categoria");

(19) Create IEA category ("categoria IEA") vectors with 1 and 2 digits associated with the project (Categoria_dig1 and Categoria_dig2);

(20) Filter only projects that have been allocated to at least one of the categories;

(21) Assemble standardized spreadsheet for the FINEP database:

(a) Item = Contrato;

(b) Fonte_de_dados (data source) = "FINEP";

(c) Data_Assinatura (signature date) = Data_Assinatura (signature date);

(d) Data_Limite (deadline) = Prazo_Utilização (term of use);

(e) Duração_meses (length in months) = periodo_meses (length in months);

(f) Valor_Contratado (contracted amount) = Valor_Finep (Finep amount);

(g) Valor_Liberado (released amount) = Valor_Liberado__2013.2019 (released amount 2013–2019);

(h) Nome_do_agente_financiador (name of funding agent) = ;

(i) Natureza_do_financiamento (nature of funding) = ;

(j) Modalidade _do_financiamento (type of funding) = ;

(k) Nome_do_agente_Executor (name of executing agent) = ;

(l) Natureza_do_agente_Executor (nature of executing agent) = ;

(m) Categoria_da_tecnologia_digito1 (digit-1 technology category) = categoria_dig1;

(n) Categoria_da_tecnologia_digito2 (digit-2 technology category) = categoria_dig2;

(o) P&D_ou_Demonstração (R&D or demonstration) = Demonstração (demonstration);

(p) Valor_Liberado_2013 (released amount in 2013) = Valor_Liberado_2013 (released amount in 2013);

(q) ...;

(r) Valor_Liberado_2019 (released amount in 2019) = Valor_Liberado_2019 (released amount in 2019);

(22) Create "final_finep.xsls" file based on standardized spreadsheet.

FNDCT Protocol

Protocol for the FNDCT database

Sequence of actions:

(1) Open file "fndct_2013 to 2018 with disbursement";

(2) Save "Consulta2" (query 2) tab as an independent file with a ".csv" extension, and name it "FNDCT.csv";

(3) Import "FNDCT.csv";

(4) Create identifier code for the projects in the database;

(5) Apply filter: select projects whose "Ano de Utilização" (year of use) is greater than or equal to 2013;

(6) Define search terms associated with the IEA category (Expert);

(7) Change text from the "Título do Projeto" (project title) variable to lowercase;

(8) Apply search terms;
   (a) Perform search on "Título do Projeto" (project title) variable using terms from category 1.1;
   (b) Create a vector that points to 1 when the term is recognized in the search variable, and 0, otherwise;
   (c) Repeat (a) and (b) for the other available categories;
   (d) Create a project-category matrix;

(9) Group the project-category matrix into the database;

(10) Calculate the contract length ("período_meses") based on the start and end dates; Projects starting and ending in the same month receive a value of 1;

(11) Calculate the amount contracted in 2013, observing the project's signature date and end date (values are distributed uniformly throughout the length of the project);

(12) Repeat previous step for years 2014 to 2019;

(13) Create vector of total contracted value for the period from 2013 to 2019 ("Valor_ Contratado_2013.2019");

(14) Create an intermediate file to check the compliance of searches ("FNDCT_interm.csv");

(15) Analyse project conformity (Expert);

(16) Import corrected project-category matrix ("projeto-categoria");

(19) Create IEA category ("categoria IEA") vectors with 1 and 2 digits associated with the project (Categoria_dig1 and Categoria_dig2);

(20) Filter only projects that have been allocated to at least one of the categories;

(21) Assemble standardized spreadsheet for the FNDCT database:
   (a) Item = ID_Agencia;
   (b) Fonte_de_dados (data source) = "FNDCT";
   (c) Data_Assinatura (signature date) = Início (start);
   (d) Data_Limite (deadline) = Término (end);
   (e) Duração_meses (length in months) = periodo_meses (length in months);
   (f) Valor_contratado (contracted amount) = Contratado (contracted);
   (g) Valor_Contratado (contracted amount) = Valor_Contratado__2013.2019 (contracted amount 2013–2019);
   (h) Nome_do_agente_financiador (name of funding agent) = ;
   (i) Natureza_do_financiamento (nature of funding) = ;
   (j) Modalidade _do_financiamento (type of funding) = ??;
   (k) Nome_do_agente_Executor (name of executing agent) = ;
   (l) Natureza_do_agente_Executor (nature of executing agent) = ;
   (m) Categoria_da_tecnologia_digito1 (digit-1 technology category) = categoria_dig1;
   (n) Categoria_da_tecnologia_digito2 (digit-2 technology category) = categoria_dig2;
   (o) P&D_ou_Demonstração (R&D or demonstration) = ;
   (p) Valor_Contratado_2013 (contracted amount in 2013) = Valor_Contratado_2013 (contracted amount in 2013);
   (q) ...;
   (r) Valor_Contratado_2019 (contracted amount in 2019) = Valor_Contratado_2019 (contracted amount in 2019);

(22) Create "final_FNDCT.xslx" file based on standardized spreadsheet.

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 in Brazil, including the amounts spent on various energy technologies and the different types of investment in the period from 2013 to 2018, contributing to an energy big push in the country.

ECLAC

Economic Commission for Latin America and the Caribbean (ECLAC)
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LC/TS.2020/62