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Review

Working towards a framework based on mission-oriented practices for assessing renewable energy innovation policies

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A B S T R A C T

Mission-oriented programs have regularly been used as innovation policies when governments (or societies) are faced with complex challenges that demand radical innovations and multiplayer coordination. Nowadays, the global climate-change question, including the energy source issue, is an example of a mission-oriented challenge. Several countries have adopted energy programs with mission-oriented characteristics. Brazil, for example, launched three programs (PAISS, PAISS 2 and Inova Energia) to foster innovations in renewable energy sources such as biofuels, solar and wind power. These programs dealt with radical innovations, big challenges and multiplayer coordination, but did not use some important mission-oriented best practices. Based on an extensive literature review, this article's aim is to present a framework developed to verify whether renewable energy innovation programs meet the requirements for being classified as mission-oriented programs. It is assumed that mission-oriented programs can contribute to the effectiveness of renewable energy innovation policies. The case of Brazil and its Inova programs is used as an example of how to apply this framework, although the latter was designed for application to any renewable energy mission-oriented program.

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1. Introduction

The landscape of global integration and the threat posed by climate change has been pushing leaders in many countries to pay closer heed to sustainable development. In this context, the

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discussion of the energy sector and the necessary energy transition is particularly important since 77% of the world's installed energy capacity is based on non-renewable sources such as coal, oil and gas (World Economic Forum, 2016). It is estimated, that 53% of the efforts needed to contain global warming should come from the energy sector (IEA, 2016).

This trend has gradually been transformed into concrete global investments in renewable energy, which have been growing in recent years, reaching US$ 285.9 billion in 2015, equivalent to an addition of 147 GW (GW) to global energy supply. This is the first time since the industrial revolution that investments in renewable sources of energy exceeded investments in fossil sources (REN21, 2016).

Important specialized energy sector institutions predict continuous growth of renewable sources in the world energy mix. The International Energy Agency (IEA) and even some oil companies like British Petroleum (BP) forecast that renewable sources will continue to rise in the next decades, becoming responsible, in relative terms, for the greater part of additional energy generation in the world. (IEA, 2015; Petroleum, 2016).

Reaffirming this trend, 195 countries, including the most important economies of the world such as China, Japan, Russia, India, Germany, France, UK and Brazil, signed a cooperation agreement in Paris during the 21st Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) in 2015. Note that the United States originally signed the climate change agreement in 2015, but the new president, Donald Trump, decided to withdraw the country from the agreement in June 2017, in accordance with one of his campaign promises (The New York Times, 2017). In this agreement these countries committed to use their best efforts to keep global warming below 1.5 °C (UNFCCC, 2016). Researchers from the UNFCCC, other institutions and specialists agree that this goal will only be reached with the improvement and diffusion of renewable energy sources and new low-carbon technologies (IEA, 2015; Petroleum, 2016; REN21, 2016; UNFCCC, 2016).

Long-term and large-scale global change necessarily involves a concerted effort by various sectors of society, with large volumes of investment and sound and well-structured public policies. The energy transition to a low carbon economy is a global challenge that demands local action to be carried out effectively.

In this scenario, and using some of its competitive advantages, Brazil has been seeking to position itself as a global leader in this transformation process. Host to two major climate conferences (Rio 92 and Rio +20), Brazil already produces 43.5% of its primary energy from renewable sources (EPE, 2015), and still has huge expansion potential in biomass (Ferreira-Leitao et al., 2010; EPE, 2015), solar (UFPE et al., 2000), wind (CRESESB, CEPEL, Camargo Schubert and True Wind, 2001) and other sources. However, the country only ranked in 69th place (1998) in the Global Innovation Index (Cornell University, INSEAD, & WIPO, 2015).

With the objective of harnessing the country's potential strategic position and also overcoming part of its deficiencies regarding the innovation environment, the Brazilian government has included the energy sector, especially renewable energy, at the center of its main innovation policy in recent years: the plan called "Inova Empresa" ("Company Innovation"). Launched in March 2013 by the Brazilian government, this plan was the largest innovation financing initiative in Brazil's recent history. From the beginning, the plan had an unprecedented budget (by Brazilian standards) of US$ 16.5 billion, just to support technological innovation in a wide range of initiatives. The core of the policy, called "Inova Programs" or "Inova Family", was composed of 11 sectorial and thematic initiatives, and corresponded to 65% (US$ 10.6 billion) of the whole budget (Brazil, 2013).

These "Inova Family" initiatives had a unique set of characteristics, which were unprecedented in Brazil, and to a certain extent worldwide as well. The most important aspect of these programs was each initiative's attempt to integrate all federal efforts around a specific theme, aiming to improve the efficiency of investments in innovation. To reach this goal, these initiatives were structured as mission-oriented programs (Mazzucato and Penna, 2015).

Three of the Inova programs (and 17% of the entire budget) were concerned with renewable energy: PAISS (2011), Inova Energia (2013), and PAISS 2 (2014). The PAISS and PAISS 2 aimed to bring Brazil "back into the game" of ethanol productivity and other advanced sugarcane bio-products. The second one, Inova Energia, targeted a wider scope, with three different lines designed to rethink the Brazilian electrical sector, calling for new technologies in smart grids, solar and wind generation, in addition to electric cars and their components (motors, batteries etc.).

Considering the energy transition scenario and based on an extensive literature review, this article's main objective is to present a framework that was developed to verify whether renewable energy innovation programs meet the requirements for being mission-oriented programs. We assume that mission-oriented programs can contribute to the effectiveness of renewable energy innovation policies. The case of Brazil and its Inova programs is used as an example of how to apply this framework. The main objective is to help assess and formulate new renewable energy policies also in other countries.

To achieve our main objective, we established the following intermediate objectives:

- Identify which characteristics a renewable energy innovation program must have to be considered a mission-oriented program;
- Develop a framework with mission-oriented constructs to verify to what extent a renewable energy innovation program/policy meets the requirements to be a mission-oriented program; and
- Apply this framework to the case of the Inova programs to illustrate how it can be used.

2. Research methodology

To achieve these objectives, it was important to first find comparable parameters to analyze renewable energy programs in terms of being mission-oriented programs. We did this by an extensive systematic literature review of mission-oriented innovation programs and policies, focused on initiatives in energy as the sector and Brazil as the region. We ran four searches in the Scopus database, restricted to the last 10 years and to articles and reviews.

In the first search we looked for mission-oriented public policies to establish recent benchmarks. Then, we used "mission-oriented" AND "public policy" keywords to conduct the search. We also searched for the concept of mission-orientation associated with innovation efforts. We used "mission-oriented" AND "innovation" as keywords in this case. We refer to these two searches as "mission-oriented searches".

To improve the scope of energy as a sector and Brazil as a region, we ran two more searches: one with "Brazil" AND "energy" AND "innovation", to increase knowledge regarding the latest efforts in energy sector innovations in Brazil; and the other using "Brazil" AND "energy" AND "public policy" to better understand public energy policies in Brazil in recent years. We refer to these other two searches as "Brazil and energy searches".

The combination of these searches returned 188 articles/reviews. We applied a thematic filter to exclude purely technical papers and restrict subject areas to those linked to the scope of this article: Business, Management and Accounting; Social Sciences; Economics, Econometrics and Finance; and Decision Sciences. We thus obtained 74 articles.

The authors of these papers totaled 189, but only six had published more than one article on the themes at issue: Yokoo, Y. (Japan); Gobbo, J. A. (Brazil); Ismail, K. A. R. (Brazil); Lino, F. A. M. (Brazil); Silveira, S. (Sweden); and Johnson, F. X. (Sweden). Even these authors had written only two articles each out of those returned by our searches. The diversity of authors on these themes, but with no single one standing out, provided us with some interesting insights, such as the prevalence of Brazilian and Swedish researches in these themes.

The timeline of the number of articles/reviews in Fig. 1 shows a growth trend in publications in the areas investigated ($\beta > 0$ and $R^2 = 0.678$). There are also more publications about Brazil and energy than the mission-orientation concept. The peak of publication about mission-orientation in 2012 occurred because a special issue of *Research Policy* was published that year, entitled: "The need for a new generation of policy instruments to respond to the Grand Challenges" (volume 41, issue 10).

Regarding journals, the most important publications in the areas of interest have the highest H Index too. The average H Index of journals with two or more publications in our searches was 50.1. The special issue of *Research Policy* propelled it to the top of the ranking. The sectorial focus of the *Journal of Cleaner Production* put it in second place. This journal also has the second highest H Index among the listed ones (Table 1).

As regards keywords, the most cited ones in mission-oriented searches were: "Innovation" (8), "Innovation Policy" (3) and "Public Procurement" (3); the others were cited only two or fewer times. The presence of "Innovation" or "Innovation policy" is not surprising because they were used as keywords in the searches, but "Public Procurement" appears as an important keyword, and none of the Inova Programs deals with it.

In the case of Brazil and Energy searches, the most cited keywords were: "Brazil" (30), "Innovation" (23), "Biofuel" (9), "Biofuels" (8) and "Ethanol" (8). "Brazil" and "Innovation" were keywords from the parameters of the searches, but the others were not, and all three were linked to the biofuels concept. This is important because despite the discovery of the subsalt (or pre-salt) oil and gas reserves, and Brazil's continentally integrated power grid, most research about energy in Brazil in the last 10 years has been directed towards biofuels.

Table 1
Top journal rankings in publications.

Rank	Outlets of Articles/Reviews	N[a]	H Index
1	Research Policy	5	160
2	Journal of Cleaner Production	4	96
3	Technological Forecasting And Social Change	3	68
4	Energy Economics	2	85
5	Technovation	2	82
6	Resources Conservation and Recycling	2	75
7	Industry and Innovation	2	41
8	Innovation	2	22
9	Foresight	2	20
10	Energy Research and Social Science	2	14
11	Environmental Development	2	13
12	Journal of Technology Management and Innovation	2	13
13	Gestão e Produção	2	9
14	Espacios	2	3

[a] N = number of articles/reviews.

After this screening process, we performed a content analysis (Weber and Robert Philip, 1990) of the articles' titles and abstracts to identify those that could help us achieve our secondary objectives, namely the development and application of a framework based on the mission-oriented benchmark constructs that we had identified in the first step of our bibliographic research. The framework was basically a checklist or chart to analyze the similarities and differences between renewable energy programs and the mission-oriented benchmarks.

To collect the data for applying our framework adequately to the case of the Inova programs, aiming to illustrate how one can verify to what extent such programs have the necessary characteristics to be effective mission-oriented programs, we resorted once again to content analysis. This technique helped to evaluate the data and information collected from different sources, notably semi-structured informal interviews with staff members of Finep (a Brazilian innovation agency) and data available at the websites of Finep, BNDES (Brazil's National Bank for Economic and Social Development) and ANEEL (National Electric Energy Agency), including program evaluation reports, public and internal presentations, official databases, public tenders and their official results, and sectorial BNDES/Finep studies (for references, see Table 4).

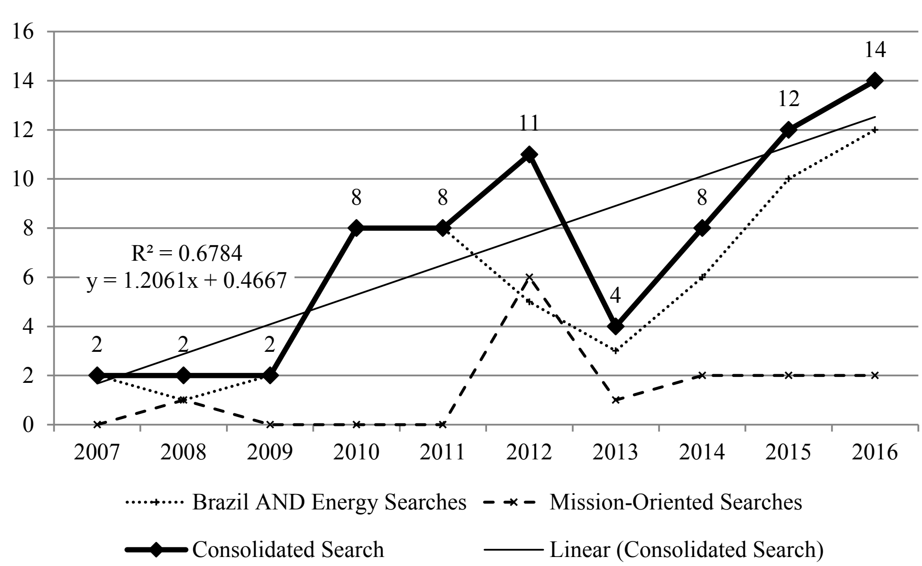

Fig. 1. Publications by years - business, management and accounting; social sciences; economics, econometrics and finance; and decision sciences.

3. Literature review

We started our literature review by looking for a definition for the central concept of our research: mission-oriented policies. For policy formulation, a correct definition of a mission-oriented policy and identification of its characteristics is critical because of economic and social implications (Amanatidou et al., 2014; Foray et al., 2012; Mazzucato and Penna, 2015). Although this central concept has been described very differently by many authors, there is a consensus that what characterizes these policies are that they are centralized and focused on contending with big national challenges (Dasgupta and Stoneman, 2005; Edquist and Zabala-Iturriagagoitia, 2012). These policies are more focused on radical innovations needed to achieve clearly set goals of national importance (Cantner and Pyka, 2001; Ergas, 1987). In contrast to those developed according to the mission-orientation concept, diffusion-oriented policies focus on providing general innovation-related public goods to diffuse technological capabilities throughout industrial infrastructure and produce a large volume of incremental innovations (Ergas, 1987).

The original mission-orientation concept was used to classify countries' policies. Researchers in the innovation policy area tried to classify countries' policies as mission- or diffusion-oriented (Cantner and Pyka, 2001; Chiang, 1991; Ergas, 1987). However, even they, and many other authors, admitted that this could be complicated because countries might adopt different strategies in different sectors, regions or innovation contexts and with different time frames (Anadón, 2012; Ergas, 1987; Hahn and Yu, 1999). We can cite as examples of changing policy directions/strategies, the defense innovation policies between 1948 and 1989 during the Cold War (Mowery, 2012); the increase in the number and direction of energy innovation policies after the 1970's oil and gas crises (Anadón, 2012); or the current discussion regarding the generation of radical innovation versus diffusion of incremental clean technologies (Eleftheriadis and Anagnostopoulou, 2015; Mazzucato and Penna, 2015). A radical innovation (Leifer et al., 2000, p. 5) “is a product, process, or service with either unprecedented performance features or familiar features that offer potential for significant improvements in performance or cost. Radical innovations create such a dramatic change in products, processes or services that they transform existing markets or industries, or create new ones.”

We assumed that mission-oriented programs can contribute significantly to enhance the effectiveness of innovation policies, including renewable energy innovation policies. This assumption is based on the studies of Amanatidou et al. (2014), Foray et al. (2012) and Mazzucato and Penna (2015), who highlight the importance and positive impact of mission-oriented policies in technology and innovation environments.

We adopted the institutional research approach, using public agents and specific programs as the unit of analysis (Dosi, 2016; Foray et al., 2012; Rumpf, 2012; Santos et al., 2014). This approach enables a more accurate analysis of the characteristics and results of policies in specific sectorial, regional and time contexts. Below we describe the characteristics of a mission-oriented program, based on the literature review.

The first is the alignment of the program with the country's general policies (economic, industrial, environmental etc.) (Ergas, 1987; Mazzucato and Penna, 2016). An example is the Chinese Renewable Energy Scale-up Program (CRESP), created to build a legal, regulatory, and institutional environment conducive to large-scale, renewable-based electricity generation. It was created in full alignment with the 10th Chinese Five-Year Plan, the national plan which establishes China's priorities (Abdmouleh et al., 2015; World Bank, 2016).

The second characteristic is the need for a clear objective involving a major challenge to be solved. Generally it involves the development of a set of new technologies to achieve this major objective. Defining measurable intermediate goals is important for managing and evaluating the progress of mission-oriented programs. The Apollo Program, whose aim was to send the first human being to the Moon, is an eloquent example of a clear objective mission-oriented program (Mazzucato and Penna, 2016; Veugelers, 2012).

The third characteristic is a focus on high impact radical innovations. It is important to be able to justify politically, economically or socially the choice of one program over another (Amanatidou et al., 2014; Dasgupta and Stoneman, 2005). By definition, in diffusion-oriented policies there is no focus on requiring the achievement of a few specific targets, so policymakers can spread funds more widely and foster more incremental innovations. An example of a mission-oriented program focused on radical innovation is the Manhattan Project to develop nuclear bomb technology during World War II (Foray et al., 2012; Mazzucato and Penna, 2016; Mowery, 2012).

The fourth characteristic of a mission-oriented program is the focus on generating new technologies instead of the diffusion of existing ones (Ergas, 1987). Some authors refer to the importance of balancing the generation of new technologies with diffusion of innovations (Glennie and Bound, 2016; Hahn and Yu, 1999), but it is widely agreed that mission-oriented programs are generally more focused on the generation of new technologies.

The fifth characteristic is the time frame for results. A long-term view is generally necessary, but less required than in the case of diffusion-oriented policies (Chiang, 1991). It also depends on the kind of mission being specified. The Manhattan Project delivered expected results in less than six years, but challenges like climate-change prevention demand much more time to be effectively addressed (Amanatidou et al., 2014; Veugelers, 2012). The concern about long-term missions versus political cycles is a significant risk factor in mission-oriented programs (Amanatidou et al., 2014).

The sixth characteristic that differentiates mission-oriented programs from other ones is the role of government. The government's priority-setting role is always critical in the mission-oriented paradigm (Ergas, 1987; Makhoba and Pouris, 2016; Mazzucato and Penna, 2015; Rumpf, 2012). But the government's role can sometimes be extended to more active participation, including the execution of part of the program in public facilities such as technological institutes, universities or companies (Mazzucato, 2016; Mowery, 2012).

The seventh characteristic refers to program governance. Mission-oriented programs generally have a more centralized decision process than other technology policies, with just one or a few government agencies making the critical decisions (Ergas, 1987; Mazzucato, 2013; Mazzucato and Penna, 2015). However, the programs' governance models can differentiate the decision process according to whether this involves setting priorities, monitoring overall progress or evaluating performance (Foray et al., 2012). Ergas (1987) emphasizes the need to centralize all decisions in one agency that can combine technical expertise, financial resources and decision-making autonomy.

The eighth characteristic refers to success factors of a mission-oriented program. The evaluation process in diffusion-oriented programs has broader indicators of success, like the number of PhDs in the private sector, percentage of GDP invested in R&D, number of innovative companies etc. (Dutta, 2011). Mission-oriented programs usually have a “mission accomplished” target (Ergas, 1987). However, mission-oriented programs have frequently generated spillovers. Defense-backed technologies such as GPS, Internet, microprocessors and touch screens, are spinoffs of mission-oriented initiatives (Mazzucato, 2013; Mowery, 2012).

The ninth characteristic concerns program participants. While other technology programs could aim at just one part of the innovation chain (universities, SMEs, big corporations, technological institutes, government facilities, regulators etc.), mission-oriented programs need to act in the whole universe of involved players and coordinate them in the same direction (Amanatidou et al., 2014; Choung et al., 2014). This big challenge is one of the reasons that a centralized governance model is required in mission-oriented programs (Cantner and Pyka, 2001). Regarding this point, Ergas (1987) recommends that the project leader be a big corporation in order to guarantee the financial support and technical quality and diversity needed to deal with the challenges and oscillations during the process.

The tenth and final mapped critical characteristic of a mission-oriented program refers to its public policy instruments. To solve a big and complex question, all efforts need to be analyzed and aligned. Table 2, based on Borrás and Edquist (2013), provides a guide to understand the diversity of innovation policy instruments that can be used in mission-oriented programs.

Note that public procurement (Edquist and Zabala-Iturriagagoitia, 2012; Lember et al., 2015; Mowery, 2012; Veugelers, 2012; Zelenbabic, 2015), as well as legal/regulatory frameworks and grants (Abdmouleh et al., 2015; Hahn and Yu, 1999; Mazzucato and Penna, 2015; Mowery, 2012; Polzin et al., 2015; Veugelers, 2012) deserve special attention as critical instruments for mission-oriented programs.

These ten characteristics and the resulting framework can be used to analyze any mission-oriented program, but some considerations have to be made in the case of renewable energy programs. First of all, we need to consider that effectively managing climate-change as a mission is a global challenge and that a solution necessarily involves many countries and many technologies (Abdmouleh et al., 2015). It is very different from a mission like sending a man to the Moon or Mars (NASA, 2016), or building nuclear bombs, which can be conducted by only one or a few countries and use one or a few central technologies.

Another question concerns specific instruments for renewable energy. The most cited is the “Feed-in Tariff” (FiT), which is a long-term contract used to guarantee the attractiveness of deals involving renewable energy generation (Eleftheriadis and Anagnostopoulou, 2015; Polzin et al., 2015). Another important indirect mechanism is specific taxes or compensatory levies for non-renewable sources like coal, oil and gas (Polzin et al., 2015).

Table 3 presents our framework for checking whether renewable energy programs have mission-oriented benchmark characteristics. Each characteristic can be classified as shown in column 2 “Classification”, based on “References” regarding benchmarks in column 3. The highlighted attribute in column 2 is considered the benchmark in terms of ensuring effectiveness of the mission-oriented program. Items #1 to #10c are general characteristics of any mission-oriented program, while items #10d and #10e more specifically apply to renewable energy mission-oriented programs.

Before presenting the results of our research, it is important to explain what the Inova programs are so we can show how our framework can be applied.

Table 2
Innovation policy instruments.

Positive incentives (encouraging and promoting):
- Cash transfers
- Cash grants
- Subsidies
- Low-interest loans and soft loans
- Loan guarantees
- Government provision of goods and services
- Private provision of goods and services under government contracts
- Vouchers
Disincentives/Regulatory (discouraging and restraining)
- Taxes
- Charges
- Fees
- Customs duties
- Public utility rates

Source: Borrás and Edquist (2013).

4. Inova renewable energy programs

The “Inova Empresa” plan had three specific renewable energy programs: PAISS, PAISS 2 and Inova Energia. These programs had some common characteristics, and it is important to understand their range and novelty. The first common characteristic was the nature of the programs themselves. Though the specific goals of each program were completely different, all of them were directed towards dealing with a really big problem that could only be solved through innovations or diffusion of new technologies. All these programs aimed to provide total support for each step in achieving these objectives, from scientific efforts, followed by development and prototyping, until the initial phase of marketing the innovations (Finep et al., 2013; Finep and BNDES, 2014, 2011).

As regards coordination, all of it was led, formulated and operated jointly by Finep and BNDES**,** The “Inova Energia” program also included ANEEL. The integration and cooperation of these key Brazilian institutions around the same goals was the first step and a big novelty of the Inova programs (Brazil, 2013). These institutions were the sponsors of each program. The related ministries (Science, Technology and Innovation; Development, Industry and Foreign Trade; Agriculture; and Mining and Energy) acted as a higher council and were more active in the macro-formulation and general evaluation of the progress achieved.

The three programs tried to combine all these sponsors' innovation support instruments. In Finep's case, this was grants and loans to universities, technological institutes, startups, SMEs and large companies. Finep could also invest in the equity of program-selected companies. BNDES used similar instruments, with the exception of grants to companies, because according to Brazilian legislation, only Finep can operate this kind of resource. The conditions and amount of funding offered by BNDES was also different. In ANEEL's case, the mechanism for supporting innovation in the program was different. One of the regulatory obligations of power companies in Brazil is to invest at least 1% of their turnover in research and development (R&D). The acceptance of these expenditures is up to ANEEL. Companies that were approved in the Inova Energia program could automatically include this R&D expenditure in ANEEL's regulatory 1% provision.

The process and governance of the programs were very similar. They started with a public tender notice in which participants needed to sign a letter of interest containing basic information about the institution (firm, university or research institute), the key team and its alignment with the notice's objectives. At this stage the sponsors simply performed a single filter of the participants, then promoted match-making events and distributed material with basic information about the approved institutions. The aim of this first stage was to introduce institutions with similar interests and technological solutions to each other in an organized and secure way.

The second step involved encouraging leading companies to form consortiums with SMEs, universities, technological institutes, etc. to provide an entire solution to one or more of the problems mapped in the public tender notice. Wider scopes of collaboration guaranteed more access to grants and better loan and investment

Table 3
Framework for analyzing renewable energy programs according to mission-oriented program benchmarks.

#	Characteristic	Classification				References
1	Alignment with General Economic/Innovation Policy	**High**	Medium	Low		Ergas (1987); Mazzucato & Penna (2016); Abdmouleh, Alammari, & Gastli (2015); World Bank (2016)
2a	Clear Objectives	**Yes**	No			Mazzucato & Penna (2016); Veugelers (2012)
2b	Big Question to be Solved	**Yes**	No			Amanatidou, Cunningham, Gök, & Garefi (2014); Dasgupta & Stoneman (2005)
2c	Number of New Technologies Involved	**One**	**Few**	Many		Foray et al. (2012); Mazzucato & Penna (2016); Mowery (2012)
3a	Innovation Degree	Incremental	**Radical**			Cantner & Pyka (2001); Ergas (1987)
3b	Potential Impact	**High**	Medium	Low		Amanatidou, Cunningham, Gök, & Garefi (2014); Dasgupta & Stoneman (2005)
4	Program Focus	**Innovation Generation**	Competence Diffusion			Ergas (1987)
5	Time to Achieve Practical Results	Short Term (less than 2 years)	**Medium Term (3 to 5 years)**	**Long Term (6 to 10 years)**	**Very Long Term (more than 10 years)**	Chiang (1991);Amanatidou et al. (2014); Veugelers (2012)
6a	Role of Government - Setting Priorities	**High**	Medium	Low		Ergas (1987); Makhoba & Pouris (2016); Mazzucato & Penna (2015); Rumpf (2012); Mazzucato (2016); Mowery (2012)
6b	Role of Government - Monitoring Overall Progress	**High**	Medium	Low		
6c	Role of Government - Evaluating Performance	**High**	**Medium**	Low		
7a	Decision Process - Setting Priorities	**Centralized (1 Institution)**	**Semi-Centralized (2 or 3 Institutions)**	Decentralized		Ergas (1987); Mazzucato (2013); Mazzucato & Penna (2015); Foray et al. (2012)
7b	Decision Process - Monitoring Overall Progress	**Centralized (1 Institution)**	Semi-Centralized (2 or 3 Institutions)	Decentralized		
7c	Decision Process - Evaluating Performance	**Centralized (1 Institution)**	**Semi-Centralized (2 or 3 Institutions)**	Decentralized		
8	Evaluation Metrics	**Specific goals**	Macro Indicators			Dutta (2011); Ergas (1987)
9a	Projects Leadership	Government	**Large Corporation**	Universities / Research Institutes	SMEs	Cantner & Pyka (2001); Ergas (1987)
9b	Participant Type (Companies, Universities etc.)	One	Few	**Many**	**All**	Amanatidou et al. (2014); Choung, Hwang, & Song (2014)
10a	Instruments (Subsides, Grants, Taxes, Procurement etc.)	One	Few	**Many**	**All**	Edquist & Zabala-Iturriagagoitia (2012); Lember, Kattel, & Kalvet (2015); Mowery (2012); Veugelers (2012); Zelenbabic (2015)
10b	Procurement	**Yes**	No			
10c	Grant	**Yes**	No			Abdmouleh et al. (2015); Hahn & Yu (1999); Mazzucato & Penna (2015); Mowery (2012); Polzin, Migendt, Täube, & von Flotow (2015); Veugelers (2012)
10d	Legal/Regulatory	**Yes**	No			
10e	Feed-in Tariff*	**Yes**	No			Eleftheriadis & Anagnostopoulou (2015); Polzin et al. (2015)

Source: The authors

conditions. The main objective of this arrangement was to foster complete innovative solutions (basic/applied research, technological development, testing and initial marketing) on the part of the participants and financial support as counterparts of the leading companies.

In the third phase, the sponsors divided the innovation and business plans sent by consortiums into specific projects. Each project was directed to a specific combination of instruments (grant, credit etc.) and sponsors (Finep, BNDES and/or ANEEL) already approved on merit. The guarantees, certifications, legal issues and other bureaucratic requirements were handled only by the specific sponsor of the project. Each sponsor had its own internal rules to be observed by participants.

During the whole process, the selection of instruments, projects and supported companies, universities and technological institutes was undertaken jointly by a technical committee composed of managers of the sponsors: representatives of BNDES and Finep sat on all committees, and people from BNDES, Finep and ANEEL were members of those related to the Inova Energia program. Once approved by a committee, the final arrangement was approved by each sponsor's board of directors.

Having a common general concept, process and governance can help the external public better understand the innovative points of these programs, but each one obviously has its own characteristics.

4.1. PAISS (2011)

The first of the Inova programs, launched even before the general Inova Empresa Plan, the PAISS (Joint BNDES-FINEP Plan to Support Technological Industrial Innovation in the Sugar-Energy and Sugar-Chemical Sectors) acted as a pilot project of BNDES-Finep institutional cooperation in the Inova Empresa Plan.

The aim of this program was to support the development, production and sale of new industrial technologies to process sugarcane biomass. The program had specific subthemes that could be aggregated into three main areas, with all of them exclusively using sugarcane biomass as raw material (Finep and BNDES, 2011).

- 2nd generation (2G) bioethanol from sugarcane;
- New biochemical products from sugarcane; and
- Gasification of sugarcane biomass.

The motivations behind this option were the huge amount of residues (bagasse, straw and leaves) produced by the first-generation bioethanol industry: 64% sugarcane biomass or 415 million metric tons a year (Ferreira-Leitao et al., 2010). The second-generation technology could increase Brazilian bioethanol production by 50% with no additional land use (Milanez et al., 2015). Biogas and other biochemicals could increase the added value of sugarcane and related industrial sectors.

As usual, the PAISS program suffered from "first-mover effects", and feedback from the players involved was used to improve the others. The program's budget totaled US$ 600 million, with US$ 300 million from Finep and US$ 300 million from BNDES (Finep and BNDES, 2011).

4.2. Inova Energia (2013)

Following the changes that were occurring in the world electricity sector, Inova Energia included ANEEL, the Brazilian electricity regulator, along with Finep and BNDES to support innovation. This inclusion was critical because most of Brazil's electricity sector operates through a centralized system and this market is highly regulated. ANEEL is also important in Brazilian R&D efforts because power distribution companies have a legal obligation to invest in innovations.

Inova Energia had three macro objectives:

- To support the development and diffusion of technological solutions for implementing smart grids in Brazil;
- To support the development and technological mastery of Brazilian companies in the solar and wind energy value chain; and
- To support industrial development and integration in the hybrid/electrical vehicle segment and foster greater energy efficiency in Brazil's auto industry.

These three goals were encapsulated into three specific lines, with a total of 10 subthemes. Here, we do not discuss each subtheme, merely the overall features.

The budget of the program was R$ 3 billion, with R$ 1.2 billion from Finep, R$ 1.2 billion from BNDES and R$600 million from ANEEL (Finep et al., 2013).

4.3. PAISS 2 - agro (2014)

PAISS 2, also known as PAISS Agro, had objectives that complemented those of the first PAISS. While PAISS focused on industrial solutions aimed at adding value to, and increasing the productivity of, sugarcane bioproducts, PAISS 2 focused on improving performance "outside and inside the gate". PAISS 2 addressed the following five lines (Finep and BNDES, 2014):

- New varieties of sugarcane with more biomass and/or total recoverable sugars (TRS);
- Equipment to improve sugarcane planting or harvesting;
- Systems for planning, managing and controlling sugar production;
- Biotechnology applied to sugarcane;
- Development of agro-industrial solutions and complementary varieties of sugarcane.

Both PAISS and PAISS 2 brought Brazil "back into the game" in the advanced biofuels world stage (Nyko et al., 2013). The PAISS 2 budget (Agro) totaled R$ 1.48 billion, with R$740 million from Finep and another R$ 740 million from BNDES.

5. Results and discussion

Below we describe some of the most significant results of the application of our framework to the case of the Inova programs, as summarized in Table 4 (note that the results in green refer to those that fully satisfy the requirements of a mission-oriented program; those in yellow only partially meet the requirements, and those in red do not satisfy any of them).

With respect to the first characteristic of an effective mission-oriented program, 'alignment' (see item 1 Table 3), we found that the Inova programs had considerable alignment with the country's macro policies (see Table 4). During the Inova program period, Brazil had two major guidelines for economic/innovation policies: the Greater Brazil Plan 2011–2014 (PBM), which acted as an industrial policy (ABDI, 2014), and the National Science, Technology and Innovation Strategy 2012–2015 (ENCTI) (Brazil, 2012). Both established renewable energy as a national priority.

As regards the second necessary characteristic 'having clear objectives' (see item 2a, Table 3), according to the documents investigated, PAISS and PAISS 2 had more specific goals and involved fewer technologies than Inova Energia. While PAISS and PAISS 2 had closer thematic points, like "Optimization of pretreatment processes of sugarcane biomass for hydrolysis" (Finep, 2011) and "New sugarcane varieties with higher amounts of biomass and/or total recoverable sugars, with emphasis on the use of transgenic enhancement" (Finep, 2014), Inova Energia had a broader approach, with thematic issues like "Support the development and diffusion of electronic devices, microelectronics, systems, integrated solutions and standards for the implementation of smart grids in Brazil" (Finep, 2013). Despite this, both objectives were very clear and their aim was to solve big questions (item 2b), such as changing the energy mix to be more sustainable (EPE, 2015; Nyko et al., 2013; Parente, 2016; UFPE et al., 2000). The large number of new technologies (item 2c), and challenges established in Inova Energia was noteworthy when compared with the literature's recommendations.

The three programs were mainly focused on radical innovations (item 3a), but Inova Energia had some incremental innovation challenges too, such as new equipment to measure bidirectional electricity flows (Finep et al., 2013). In addition, the three were more focused on generating new products (item 4), processes and technologies instead of just improving or diffusing existing solutions (Finep, 2014, 2013, 2011).

The innovations demanded by PAISS, PAISS 2 and Inova Energia required a long time frame (item 5 in Table 3 and results for this item in Table 4) to reach practical results, but for different reasons. The two biggest players in biofuels market, the U.S. and Brazil, have been investing in this technology since the 1970s (Allaire and Brown, 2015; Milanez et al., 2015). The challenges of biotechnology and advanced chemicals usually require a long time to overcome. For different reasons, systemic changes in the energy mix, as expected in Inova Energia outputs, also demand a longer-term view (British Petroleum, 2017; WWF et al., 2011).

The role of government (item 6a) was critical throughout the process – setting priorities, monitoring progress, and evaluating performance – of the three programs. All the discussions and application of subsidies were carried out by national agencies (Finep, BNDES or ANEEL) or ministries. The General Committee was composed of representatives from five ministries important to the economy (Office of the President, Finance, Science & Technology, Industry & Commerce, and Small Business), and this committee was responsible for setting priorities, monitoring overall progress and evaluating performance (BNDES, 2011; IEA/USP, 2013).

But regarding this point, we found an important difference when we compared the Inova programs based on the documents

Table 4
Results of application of framework: Case of renewable energy inova programs.

Characteristic	PAISS		PAISS 2		Inova Energia	
	Classification	References	Classification	References	Classification	References
Alignment with general Economic/Innovation Policy	High	*ABDI (2014); Brazil (2012)*	High	*ABDI (2014); Brazil (2012)*	High	*ABDI (2014); Brazil (2012)*
Clear Objectives	Yes	*Finep & BNDES (2011)*	Yes	*Finep & BNDES (2014)*	Yes	*Finep, BNDES & ANEEL. (2013)*
Big Question to be Solved	Yes	*Nyko, D. et al. (2013); Parente, P. (2016)*	Yes	*Nyko, D. et al. (2013); Parente, P. (2016),*	Yes	*CRESESB, CEPEL, Camargo Schubert, & TrueWind. (2001); EPE (2015); UFPE, CEPEL, & CHESF. (2000).*
Number of New Technologies Involved	Few	*Finep & BNDES (2011)*	Few	*Finep & BNDES (2014)*	Many	*Finep, BNDES & ANEEL. (2013)*
Innovation Degree	Radical	*Finep & BNDES (2011); Nyko, D. et al. (2013)*	Radical	*Finep & BNDES (2014); Nyko, D. et al. (2013)*	Radical / Incremental	*Finep, BNDES & ANEEL. (2013); IEA (2015); REN21 (2016)*
Potential Impact	High	*Nyko, D. et al. (2013); Parente, P. (2016),*	High	*Nyko, D. et al. (2013); Parente, P. (2016),*	High	*IEA (2015); REN21 (2016)*
Program Focus	Innovation Generation	*Finep & BNDES (2011)*	Innovation Generation	*Finep & BNDES (2014)*	Innovation Generation	*Finep, BNDES & ANEEL. (2013)*
Time to Practical Results	Long Term (6 to 10 years)	*Allaire & Brown (2015); Milanez et al. (2015)*	Long Term (6 to 10 years)	*Allaire & Brown (2015); Milanez et al. (2015)*	Long Term (6 to 10 years)	*British Petroleum (2017); WWF, Ecofys, & OMA (2011)*
Role of Government - Setting Priorities	High	*BNDES (2011); IEA/USP (2013)*	High	*BNDES (2011); IEA/USP (2013)*	High	*BNDES (2011); IEA/USP (2013)*
Role of Government - Monitoring Overall Progress	High	*BNDES (2011); IEA/USP (2013)*	High	*BNDES (2011); IEA/USP (2013)*	High	*BNDES (2011); IEA/USP (2013)*
Role of Government - Evaluating Performance	High	*BNDES (2011); IEA/USP (2013)*	High	*BNDES (2011); IEA/USP (2013)*	High	*BNDES (2011); IEA/USP (2013)*
Decision Process - Setting Priorities	Decentralized	*Finep & BNDES (2011)*	Decentralized	*Finep & BNDES (2014)*	Decentralized	*Finep, BNDES & ANEEL. (2013)*
Decision Process - Monitoring Overall Progress	Semi-Centralized (2 Institutions)	*Finep & BNDES (2011)*	Semi-Centralized (2 Institutions)	*Finep & BNDES (2014)*	Semi-Centralized (3 Institutions)	*Finep, BNDES & ANEEL. (2013)*
Decision Process - Evaluating Performance	Decentralized	*Finep & BNDES (2011)*	Decentralized	*Finep & BNDES (2014)*	Decentralized	*Finep, BNDES & ANEEL. (2013)*
Evaluation Metrics	Specific goals		Specific goals		Specific goals	
Projects Leadership	Private companies	*Finep & BNDES (2011)*	Private companies	*Finep & BNDES (2014)*	Large Corporation	*Finep, BNDES & ANEEL. (2013)*
Participants Type (Companies, Universities etc.)	All		All		All	
Instruments (Subsides, Grants, Taxes, Procurement etc.)	Few/Many		Few/Many		Few/Many	
Grant	Yes		Yes		Yes	
Procurement	No	*Finep & BNDES (2011)*	No	*Finep & BNDES (2014)*	No	*Finep, BNDES & ANEEL. (2013)*
Legal/Regulatory	No		No		Yes	
Feed-in Tariff*	No		No		No	

investigated using our framework (Table 3) and other literature review findings. The literature strongly recommends that this process be conducted in a centralized manner. The top governance of Inova programs was conducted by five ministries and two agencies: Finep and BNDES (Brazil, 2013). Operational issues, such as selecting and monitoring projects, were dealt with by Finep and BNDES in PAISS and PAISS 2, and included ANEEL in the case of Inova Energia. Each agency had its own internal approval process, budget and other rules, which resulted in an increase in the programs' management complexity, as observed in the public tender notice in both cases.

> "The support indicated in the Joint Support Plan will depend on compliance with the usual processes of each sponsor institution, including technical, finance, legal and guarantee analysis, as well as the approval, contracting and follow-up processes."
>
> Finep et al. (2013, p. 3, p. 3)

All their evaluation metrics (item 8) are in line with the literature, targeting specific goals such as 2G ethanol enzymes or high-performance pretreatments in PAISS (Finep and BNDES, 2011), biotechnological seedling manipulation or new sugarcane varieties with more biomass in PAISS 2 (Finep and BNDES, 2014), and new supercapacitor/battery technologies or thin film solar panels in the case of Inova Energia (Finep et al., 2013).

The three programs considered that all kinds of institutions (item 9b) (universities, technology institutes, SMEs etc.) were eligible to send proposals, but each project needed to be led by a private company. Inova Energia advanced in this issue and proposals had to be led by a corporation with a minimum of resources to support the project as an integrated solution, as is evident in the literature (Cantner and Pyka, 2001; Ergas, 1987), and as is stated clearly in the official website of the program.

> "6.2. Lead Companies —Independent companies or those belonging to business groups whose gross operating revenues are equal to or greater than US$ 16 million, or total equity is greater than US$ 4 million in the last fiscal year are eligible to submit Business Plan proposals. They can do so individually or in partnership with companies of any size or with science and technological institutions."
>
> Finep et al. (2013, p. 10, p. 10)

This format is completely aligned with what is recommended in the literature, and helped to increase the breadth and robustness of proposed solutions.

Lastly, these Inova programs had a good set of financial instruments, such as grants, subsidized loans and equity options, but they were restricted to merely financial instruments (Finep, 2014, 2011). Inova Energia had the R&D expenditure obligation specified by ANEEL, but in practical terms this was very similar to a financial instrument (Finep, 2013). According to the literature, the most important instruments for mission-oriented programs are grants, procurement and legal/regulatory incentives (items 10a, 10b, 10c). The Inova programs were not able to incorporate procurement or substantial legal/regulatory incentives and provided smaller grants than the other financial instruments — 73.4% of the available funds were subsidized loans (Brazil, 2013).

Table 4 reveals that most mission-oriented constructs were used by the Inova programs to reach their goals, including the main ones: alignment with major policies, clear targets, and radical innovation generation. However, the decentralized governance of the programs and their lack of integration with legal/regulatory and procurement instruments deserve some attention. Together, they constitute two important operational points that could have caused the programs to deviate from their planned route.

It is important to emphasize, however, that the Inova renewable energy programs are still ongoing. In particular, the Inova Energia and PAISS 2 are too recent to analyze any of their results. Indeed, the selection and contracting process takes up to two years to complete. The projects themselves take up to five years, depending on the extent of the challenge and the solution's level of radicalness. The first results of PAISS are only materializing now and can be divided into expectations and reality. As regards expectations, the program put Brazil back on the map of advanced biofuels producers, as shown in Fig. 2.

The previous reality was different. When the PAISS was launched in 2011, the price of crude oil stood at over US$ 110.00/barrel. In the middle of 2014 the price fell dramatically and since then has fluctuated between US$ 30.00 and US$ 60.00 (Parente, 2016). During this same period, the sugar price almost doubled (NASDAQ, 2016). This large change in relative prices led to the postponement of all investments in sugarcane ethanol precisely at the end of the development cycle of 2G ethanol technologies. Other factors, like infrastructure, logistics, interest rates, exchange rates and political (in)stability in Brazil, as well as the policy changes in the US and EU, also influenced this situation, but this is not the focus of our research. Inova Energia and PAISS 2 are much too recent to analyze any of their results.

As a country, Brazil has the potential to be a big global player in terms of renewable energy. Its continental dimensions, high incidence of solar radiation, the unexplored wind and hydro power potential, and the urban and agricultural biomass surplus, all place it in a privileged position in the renewable energy market.

The aim of PAISS, PAISS 2 and Inova Energia was not only to bring to Brazil the application of renewable energy generation, but also to boost these industries' innovations and production chains. They were a great advance in terms of innovation policies in Brazil, and the integration of financing instruments and federal institutions in the same direction was unprecedented and desirable. But despite this great alignment of objectives, some issues limited the programs' reach, notably the design of their governance and lack of critical instruments.

As regards the instruments, most funds were composed of subsidized loans (73.4%), a policy instrument that is not fully appropriate for radical and high-risk innovations. The low level of grants available put a cap on the programs' ambitions. In 2011 alone, the US Department of Defense (DoE) provided 68 times more grants than the sum of PAISS, PAISS 2 and Inova Energia grants during the whole process (Anadón, 2012; Brazil, 2013).

The lack of formal integration with regulatory, procurement and fiscal efforts is a point that should be observed in future efforts. During the period, some of the government's actions were even at odds with incentives for biofuel and renewable electricity sources: coal/gas thermoelectricity auctions (to provide emergency energy security) or gasoline prices artificially kept at low levels (to control inflation) are two examples.

The governance of the programs could be improved according to the identified benchmarks. The number of institutions setting priorities, monitoring the process and evaluating performance delayed the process and made priority investments and project integration less effective than they could have been. In the Inova Energia case, the scope became wider than it should have been to foster a real transformation in the sector. The lack of integration of the operational systems and processes of Finep, BNDES and ANEEL also hampered integration efforts.

One of the programs' strong points was the collaborative design of phases. In each selection step the participant could build new relationships. Official events, workshops and technology supply books helped the participants to establish cooperation agreements and improved their projects during the process. This suggests alignment between mission-orientation and open innovation (Chesbrough, 2003) concepts.

As mentioned in the literature review, it is important to address specifically the case of biofuels. Brazil had success in this respect starting in the 1970s, when the mission-oriented Proálcool program created complete infrastructure for sugarcane ethanol consumption (from sugarcane planting to ethanol sale at the pump). In this respect, the flex-fuel powertrains developed at the beginning of the 2000s also deserve attention (Mazzucato and Penna, 2016). It is relevant here that PAISS and PAISS 2 helped to provide the sector with a new direction, aimed at increasing productivity and

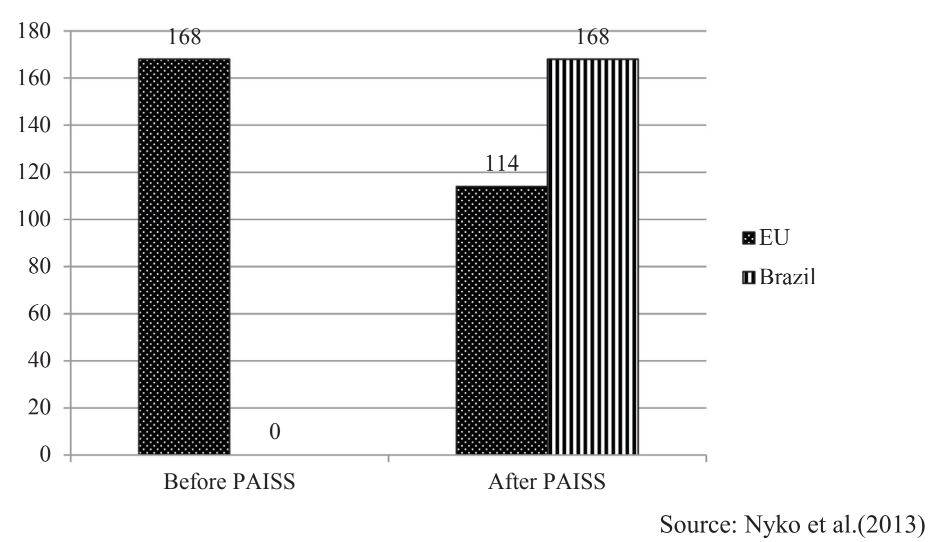

Fig. 2. 2G Ethanol production estimated for 2015 (in millions of liters).

international competitiveness.

In the electricity sector, Inova Energia contributed with some important technology inputs, although in the nationally integrated electricity grid, the critical issue is regulation. The role of energy auctions and smart grid rules were much more critical to accomplishing the program's mission than the technologies themselves. In the case of the electric/hybrid vehicle powertrains and batteries line, the main question was the difficulty of setting national priorities. The pre-salt hydrocarbon discoveries, incentives for biofuels (including PAISS and PAISS 2) and the strategy of multinational automobile companies in Brazil (they preferred to keep their electric vehicle R&D efforts at home) sent contradictory signals to investors in this sector.

6. Suggestions for future research and limitations

The main contribution of this study is to be a starting point to formulate, classify, assess and evaluate concluded, operating or future mission-oriented renewable energy programs. Therefore, suggestions for future research are particularly relevant.

One point that should be emphasized is the fact that out of the 189 authors found, only six had more than one article published on the subject in question. This may have to do with a lack of specialists, of consensus or of interest in this field, reasons that could be investigated in future studies, such as longitudinal investigations into the results of not only Inova programs, but also renewable energy mission-oriented programs in other countries.

Another suggestion is the application of the proposed framework (Table 3) to help evaluate the impact and results of the Inova programs, or compare the biofuels mission-oriented programs in Brazil, United States, Europe, China and other countries. Correlating the results of such assessments and comparisons with innovation or climate-change mitigation results from a longitudinal perspective would be particularly interesting.

We also recommend that when applying the framework in other countries to gain insights for policymakers, comparisons between countries should consider different institutional contexts.

The advances in knowledge, even if the mission goals are not reached, and the adequate time to reach each goal, are other important issues to be discussed in a much deeper analysis of renewable energy programs from a mission-oriented perspective.

Evaluating not only the program, but also agencies' internal processes, including management, competencies and technical expertise, could provide new insights into the coordination, monitoring and instrumental operation design. This would enable better identification of the strengths and weaknesses of these programs.

A survey to transform the qualitative analysis of mission-oriented constructs into a quantitative one could contribute to a better understanding of the factors involved and produce more finely tuned suggestions.

Last, but not least, the combination of mission-orientation and open innovation concepts could help find new relevant constructs for mission-oriented programs in the energy transition scenario, regardless of the country of interest.

Our study had some limitations. The parameters of some mission-oriented constructs could be better defined through a structured survey using a Likert scale. Another limitation has to do with the evaluation of the programs' results, a particularly important issue, although this was not the focus of our article. The evaluation process is not formalized or described in the literature, or in official documents or reports. Obviously, the task of establishing a cutoff point for mission accomplishment and of evaluating the externalities of these programs has become harder. In the Inova programs, for example, two significant exogenous factors also create some noise in program evaluation: the dramatic drop in oil prices since 2014 and the current economic and institutional crisis in Brazil, which began at the end of 2015.

7. Conclusions

Our main objective was to propose a framework developed to verify to what extent renewable energy programs have the characteristics of mission-oriented programs, and thus to contribute to the effectiveness of renewable energy innovation policies. The case of Brazil and its Inova programs was used as an example of how to apply this framework. The wider objective was to help with the formulation, comparison and evaluation of renewable energy mission-oriented programs also in other countries and contexts.

We started our research with an extensive literature review to find the general and renewable energy specific characteristics of mission-oriented programs with a view to developing the framework (Table 3). Next, we used the data from reports, studies, official documents, official websites, public notices etc. regarding the three most recent renewable energy mission-oriented policies in Brazil — the Inova programs - to illustrate how the framework can be applied.

More than an analysis of the three programs addressed in the research, our study sought to consolidate knowledge on the characteristics of mission-oriented programs. This type of public policy has great appeal for applications that involve major challenges, which are complex and require extensive multi-institutional coordination. The framework (Table 3) was developed for application to any energy mission-oriented program. In fact, it was developed as an analytical tool to be used by public policymakers who are dealing with challenges of this nature in the energy sector without being restricted to a specific country. We believe this is the main contribution of this research.

However, depending on the country, some adjustments may have to be made to our framework. In this respect, where the energy sector is concerned the discussion of the support instruments (item 10 of Table 3) is fundamental. Indeed, the presence of specific regulations and the commodity characteristic of the sector can enable, or restrict, a specific group of new instruments such as tariff incentives, restrictions on the use of polluting energy sources or government purchases. It is necessary to identify the set of instruments that is appropriate for the energy policy of each country, considering its demographic, geographic, political and economic characteristics. Mission-oriented programs for countries with large biomass production such as Brazil, India and the United States are likely to be quite different from those in countries with a larger presence of nuclear energy such as France, coal like China and South Africa, or oil and natural gas like Russia. From the portfolio of public policy instruments, choices appropriate to national contexts can make the difference between a successful or unsuccessful program in the context of the transition to a low carbon economy.

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