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Environmental licensing challenges for the implementation of photovoltaic solar energy projects in Brazil

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ABSTRACT

The demand for solar sources of electrical energy is increasing in the Brazilian electricity market. Investments in the sector are expected to significantly increase, thereby creating a demand for a reliable environmental licensing process. Analysis of the international regulatory frameworks allows for a critical comparison to national- and state-level frameworks. The results obtained via this comparison have helped to identify different assessment criteria that can be used to define the typologies for environmental studies for the Brazilian states included in this study, and to show the subjectivity of the process. The development of guidance regulations is also recommended to establish more universally applicable criteria. The proposed adjustments aim to reduce the risks of delays, unexpected costs, and availability of the projects, thereby increasing reliability for electricity sector planning, the investors, and the consumers.

1. Introduction

The diversification of the energy matrix is garnering the attention of researchers throughout the world including Brazil. Electricity generated from alternative sources, such as wind and solar, has the potential to increase the reliability of the electricity sector, as it can be used to complement other sources of electricity.

The number of renewable energy sources is increasing; the corresponding increasingly diverse technological advances have resulted in reduced costs and increased competition within the renewable energy field (Nascimento, 2017). In Brazil, solar energy generation is realized through the use of technologies such as photovoltaics (solar PV) and heliotherms.

The International Energy Agency (IEA, 2018) recently presented a global solar energy overview that showed that, in 2016, the cumulative solar PV capacity nearly reached 300 GW, and generated more than 310 TWh. These numbers are 26% higher than those registered in 2015, and represent just over 1% of global power output. Solar PV is expected to facilitate the growth of renewable energy capacity within the next five years, with increases exceeding 110 GW per year, most notably in China. Fig. 1 shows the solar PV cumulative capacity for each region (2017–2023).

According to the IEA (2018), considering the prevailing market and policy framework, renewable energy capacity is expected to increase by more than 1 TW between 2018 and 2023, corresponding to a growth of approximately 250% (*main case forecast*). In the case of an *accelerated case forecast* (i.e., an optimistic scenario that illustrates how policy, regulatory, and financial enhancements can affect renewable deployment), by 2023, renewable energy capacity growth could be 10% higher than the original case, reaching approximately 1.1 TW.

Solar PV represents half of the growth attributed to the *accelerated case*. Driven by faster cost reductions, which improve the technology's global competitiveness, annual solar PV additions are expected to reach 140 GW by 2023. Projected financial attractiveness and policy support improvements are especially relevant to achieve growth in Latin America and Africa (IEA, 2018).

The potential for solar PV energy use in Brazil has been highlighted in several studies. According to the Brazilian Atlas of Solar Energy (Pereira et al., 2017), it is possible to generate more solar energy in the least sunniest place in Brazil than in the sunniest place in Germany.

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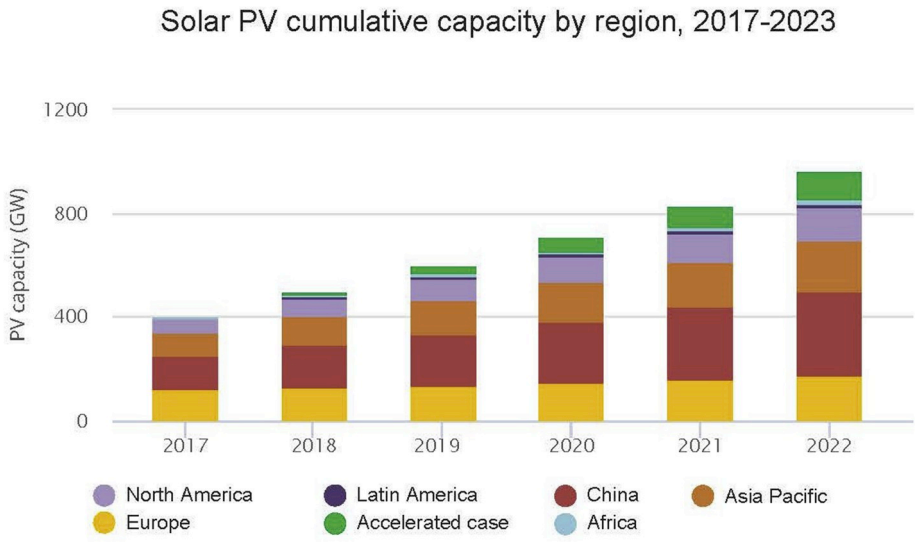

Fig. 1. Solar PV generation and cumulative capacity by region (2017–2023). Source: IEA, 2018.

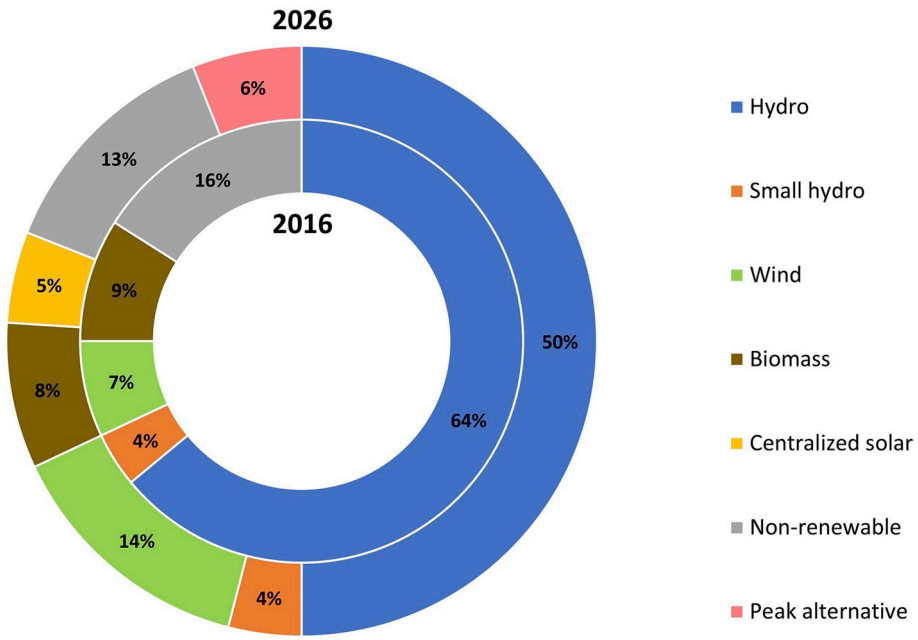

Fig. 2. Evolution of the installed capacity of various alternative energy sources in Brazil between 2016 and 2026. Source: Adapted from PDE 2026 (Brazil, 2017).

Even the regions with the lowest levels of solar radiation in Brazil have the potential to generate large amounts of energy, and small-scale use of solar power is already widespread. Solar radiation levels in Brazil vary between 8 and 22 MJ/m^2 per day. By comparison, these levels are similar to those in India, where the highest levels can be found in the western region of Rajasthan (14–25 MJ/m^2 day), and are significantly higher than the levels found in the largest European market in 2017 – Germany (8–12 MJ/m^2 day) (Pereira et al., 2012; IEA, 2018).

The Energy Research Company (EPE) is responsible for energy-sector planning in Brazil. Once a year, the EPE publishes the Decennial Plan for Energy Expansion (PDE), which presents a 10-year plan for scenarios and projections for electricity generation and transmission capacity. The PDE 2026 is the Decennial Plan used in this research.

References for the next decade are presented in the PDE 2026 (Brazil, 2017). A highly significant recommendation is the installation of 9641 MW of solar energy, 2641 MW of which has already been contracted (94 projects totaling 70% in the northeast, 29% in the southeast, and 1% in the central-western and northern regions); the remaining 7000 MW is expected to be contracted in the same regions.

Fig. 2 compares the projected 2026 installed capacity to that of 2016. It illustrates a scenario in which the diversification of renewable energy sources increases in spite of the restrictions necessary to develop hydroelectric plants with reservoirs that have enough capacity to satisfy all of the operational flexibility-related system requirements (Brazil, 2017). The graph highlights growth in the installed capacity of solar energy (yellow), which is projected to increase from an insignificant proportion in 2016 to 5% in 2026. This shows how important it is to project this source in the Brazilian electrical matrix.[1]

[1] "Peak alternative" corresponds to alternative generation plants that provide operational flexibility to the integrated system, such as open-cycle thermo-electric plants, reversible power plants, batteries, or demand management. With the inclusion of these alternatives, a portion of the installed capacity will be powered for a few moments to prevent fluctuation or failure of the energy

The cost reductions presented in the study, as determined by the Fraunhofer Institute for Solar Energy (Fraunhofer ISE, 2015), show a significant increase in solar PV energy in the electrical matrix. This is not only applicable in Brazil, but also worldwide.

To stay on course with the projections to implement solar PV generation projects in Brazil, an adequate regulatory structure is required. In 2004, 2012, the National Electrical Energy Agency (ANEEL) defined two important regulations for the sector: Resolution 77/2004 and Resolution N°. 482/2012. The first resolution provides a reduction in the transmission and distribution tariffs for companies that utilize renewable sources (ANEEL, 2004); the second resolution defines mini- and micro-generation for the purposes of network generation compensation for consumption (ANEEL, 2012). However, these regulations do not include programs or incentive schemes, such as those in the United States, Canada, Germany, Spain, and China. These countries have robust and comprehensive policies for solar energy projects, including regulatory policies, which offer financial incentives, research and development incentives, renewable energy education, and other relevant issues (Pinto et al., 2016).

Regarding environmental licensing, its procedures are alleged to be the main reason for delays to delivering projects, mainly those applied to energy (Förster and Amazo, 2016; Lima and Magrini, 2010). Santos (2017) mentioned that some difficulties regarding solar PV energy generation may exist, as there is no standardized federal licensing typology. Conversely, different state requirements have been established for each individual state; this will be further discussed in a subsequent section.

In general, the licensing process and typology for an environmental study are defined as based on environmental and engineering assessment criteria such as the affected area, installed capacity, and whether the project is located in an environmentally sensitive area.

To identify these assessment criteria and determine how they will be applied to energy-sector planning in Brazil, it is well worth studying the environmental indicators applied in other countries, such as China, Australia, India, and the United States, as well as the European Union. Referencing this information will make it possible to understand the challenges that will be faced in this expanding sector.

1.1. Research goals

The objective of this study was to identify and evaluate the assessment criteria that define the typologies for domestic and international environmental studies and their respective levels of complexity, aiming to improve and expedite the environmental permitting process for solar PV projects. By that, this process will not become a critical path for the implementation of such projects in the Brazilian electric sector.

2. Material and methods

To achieve the expected results, bibliographic and exploratory research on the regulatory and procedural milestones of the environmental licensing process were conducted.

The United States, China, Germany, and other countries in the European Union have incentive programs to implement solar energy projects, and are responsible for the worldwide expansion of this market (Dinçer, 2011). For a more comprehensive comparison, Australia and India were included in the research, as they are similar in size to Brazil, with Brazil, Australia, and India being the 5th, 6th, and 7th largest countries in the world, respectively (World Atlas, 2019); furthermore, the global horizontal irradiance (GHI) is similar, according to the Global Solar Atlas (World Bank Group, 2019). These countries were selected as objects of this study because their regulatory and procedural frameworks can be used as a basis for the analysis of the national experiences described in this study.

Hereafter, this paper discusses the environmental licensing process, and the environmental studies associated with solar PV plants that are being conducted in various countries. This information was compared to the national criteria to identify differences and similarities.

At the national level, 10 states were selected based on two main criteria:

I. Potential of solar energy: The northeastern, central-western, and southeastern regions of Brazil have the highest average annual incomes, according to the results presented in the Brazilian Atlas of Solar Energy (Pereira et al., 2017). Thus, the states of Bahia, Ceará, Piauí, Paraíba, Rio Grande do Norte, and Goiás were selected for study;

Ii. Significance of generation-consumption proximity: close proximity of the generating centers to the consumers can reduce the impact and costs associated with the implementation of power transmission lines. The states of Minas Gerais, São Paulo, Rio de Janeiro, and Paraná were selected because they represent the largest consumer centers in Brazil (southeastern/center-western and southern regions), and already have comprehensive initiatives for the implementation of solar PV energy projects (Brazil, 2017).

Regarding the environmental licensing of generation parks, the assessment of regulatory frameworks at the federal and state levels is necessary to establish the relevant environmental criteria and thus define the typology for the environmental study. These regulations affect the progress of the licensing process, as carried out by a competent environmental agency.

3. Results

3.1. International regulatory and procedural milestones

In the United States, the Department of Energy is the authority responsible for conducting the environmental review process, which assesses the need for licensing and defines the environmental studies applicable to the enterprises. The legislation (United States of America, 2018a, b) indicates that licensing is not required for solar PV installations that require less than or equal to 10 acres (approximately 4 ha) when the installations are located in anthropized areas and adhere to local zoning. These projects are submitted to a process referred to as Categorical Exclusion (CATEX).

When CATEX is not applicable, the planned area is visited to estimate the impact of the project on tribes, cultural, biological, and geological resources, land use conflicts, air and water quality, and the aesthetics of the environment. An environmental analysis, i.e., the Environmental Assessment (EA), is then carried out by funding the relevant body for the proposed action. If no significant impact is identified, the relevant authority issues a Finding of No Significant Impact (FONSI) statement, making public its understanding that there will be no significant impact associated with implementation of the action.

However, if the impact is considered to be significant, an Environmental Impact Statement (EIS), which is a comprehensive and in-depth environmental study equivalent to the Environmental Impact Assessment (EIA), is prepared. With this statement, the area of the enterprise is clearly defined (both extension and location) as one of the main criteria for environmental studies.

A joint EIS, i.e., the Solar Programmatic EIS (PEIS), has been prepared by federal institutions in six southwestern states in the United States: Arizona, Colorado, New Mexico, California, Nevada, and Utah. These states are best suited for solar energy generation. This project defines the areas in which the environmental impact associated with the implementation of solar projects would be relatively less harmful to the natural and social resources. The Solar PEIS aims to facilitate the development of this type of project in the country according to the Solar Energy Program (Solar Energy Development Programmatic EIS, 2018).

(*footnote continued*)
supply during the peak demand period (Brazil, 2017).

In Canada, the process of assessing projects is carried out by the Canadian Environmental Assessment Agency (CEAA), which classifies projects based on the description, contributions from civil society, and other relevant regional studies. The agency then reviews this information and decides whether the project should be subjected to an EIA. If an assessment is determined to be necessary, there are two types that can be conducted: (1) a standard assessment by a responsible body, or (2) a more comprehensive assessment by a review panel[2] comprised of a group of experts with no conflicts of interest (Canada, 2018; Canadian Environmental Assessment Energy, 2018, Canada Regulations Designating Physical Activities (SOR/2012-147), 2018). According to the survey, renewable energy projects are no longer subject to the prevailing legislation in the country, i.e., the Environmental Assessment Act (Ontario, 2018), but are subject to the specific legislation of each province. According to Bryansky et al., (2018), Canadian solar and wind energy projects are governed according to different levels of regulation and environmental criteria throughout the country.

For example, in 2009, the province of Ontario introduced the Green Energy Act, through which it established the Renewable Energy Approval (REA), which is applicable to certain solar projects. According to this law, ground-mounted solar installations with a capacity exceeding 10 kW require an REA, consultation with the public, municipalities, and aboriginal communities, and assessment and mitigation of its impact (Ontario, 2018).

In China, environmental studies are grouped into three categories: (A) an Environmental Impact Report (EIR), which is applicable to high-impact projects; (B) an EIR Form, which is applicable to projects considered to have a moderate impact; and (C) an Environmental Impact Registration Form, which is applicable to low-impact projects. It is up to the entrepreneur to find and commission a competent agency to define whether a complete EIR is needed; this EIR must be supported by an environmental impact form issued by the entrepreneur that describes the project and its projected large-scale environmental impact. In general, large projects with significant impact, or minor projects in more sensitive environmental areas, require a more thorough and in-depth investigation (China, 1989, 2003; Wang et al., 2003).

After the environmental impact form is processed, the agency conducts a preliminary study and determines the type of analysis to be performed (GlassonTherivelChadwick, 2005). This decision is based on two main criteria: (i) the discharge of pollutants, particularly the volume, type, and complexity of the comprising substances, as well as suggestions to minimize the corresponding environmental impact; and (ii) the existing sensitive areas with ecological, archaeological, and cultural importance, as well as human sensitivity. Other certain considerations associated with the characteristics, size, output, and environmental parameters of the project are used to group them into Categories A, B, or C (Wang et al., 2003).

The European Union was also considered for this study, particularly because of the large projects in Spain and Germany. It is important to highlight the Directive 2011/92/EC, which defines the need to apply the EIA to a number of relevant project types, and the information that must be presented in the relevant studies. The directive also defines projects that the member countries must evaluate on a case-by-case basis. The generation of electrical energy is framed in the second case; however, there is no specific information for solar PV-sourced generation.

Under Directive 2011/92/EC, member countries are obligated to develop legislation regarding EIA applicability that is customized to suit to the peculiarities and priorities of each country. One example is Law 151-B/2013 in Portugal, which requires that an EIA and Environmental Impact Study be prepared for industrial installations that produce electrical energy with a capacity of at least 50 MW, or 20 MW in more environmentally sensitive areas (European Commission, 2011, 2018; Portugal, 2013).

Spain, particularly, the Autonomous Community of the Balearic Islands, has similar legislation: Law 11/2006. This law establishes that solar PV installations, including their network connection cables, with a capacity exceeding 100 kW, or 10 kW in environmentally protected areas, will be subject to an EIA based on the respective Environmental Impact Study (Spain, 2006; European Commission, 2011, 2018).

In Germany, the Environmental Impact Assessment Law (UVPG) defines the cases for which an EIA is required, and regulates federal environmental licensing. Among other projects, the law is applicable to renewable energy projects involving wind and biogas. However, there is no mention of solar PV generation. The approval process for this type of enterprise is typically carried out by the respective municipality, which determines whether a project does not violate any municipal zoning restrictions (Germany, 1990; Solar Cluster Baden-Württemberg e.V., 2019).

The municipalities are encouraged to establish priority areas for solar PV plants by assessing local factors, thereby avoiding conflict with environmentally protected areas, and areas where the fauna and agriculture could be significantly affected. Zoning for the installation of solar PV plants requires the municipality to prepare an environmental assessment that determines and assesses the environmental impact of the activity. Solar generation ventures can then be deployed and operated in priority areas, requiring only a simplified municipal license. However, there are specific clauses that mandate compensation for disturbing the environment; these are applied on a case-by-case basis according to the local conditions (Baden-Württemberg, 2018; Solar Cluster Baden-Württemberg e.V., 2019).

According to Martin and Rice (2015), Australia faces challenges regarding renewable energy projects, as there is no single-policy approach for permits, project approvals, or implementation. The permitting process is a multi-layer operation involving federal, state, and local governments. The developer must submit the proposed activity to the responsible authority, and that proposal is then referred to the Planning Minister. This complex procedure is regulated by a large number of federal, state, and local policies and regulations, and diverse legislation, such as the Large-scale RE Target (LRET) and Environment Protection and Biodiversity Conservation Act (EPBC).

The Department of Environment in Australia manages the EPBC Act, which describes the assessment and approval processes for national environmental and cultural concerns, especially if the planned location is an area of national environmental significance. This type of area refers to specially protected areas such as World Heritage and national heritage sites, wetlands, the habitats of threatened or migratory species, federal marine areas, and nuclear sites. If the environmental impact of the activity is localized, i.e., only affecting environments such as parks, local heritage sites, air, or water, the licenses and permits can be issued by state or local governments (Australia, 2019).

In India, during their planning phase, all renewable energy projects must be reported to the centralized Ministry of Environment and Forests (MoEF), and the corresponding Pollution Control Board (PCB) at the state level. At the beginning of a project, the EIA Notification (2006) and its amendments must be applied to determine whether Environmental Clearance (EC, License or Permit) is required. In 2016, the MoEF, in consultation with the Central Pollution Control Board, reclassified the industries, defining a pollution index: red, orange, green, and white. Wind and solar projects are classified as “white” industries, and do not require an EC, as the long-term, adverse environmental impact of these projects is considered to be of minor importance. Specific permits may be required if the project is located in

[2] Review Panel: A review panel is a group of independent experts appointed by the Ministry of the Environment to conduct an environmental assessment. These experts are selected based on their knowledge, experience, and expertise, and must be free of any conflict of interest with the designated project. A review panel determines whether the environmental impact statement prepared by the proponent is sufficient to proceed to public participation (Canada Basics of Environmental Assessment, 2019).

forested areas (under the Forest Conservation Act), or located within the boundaries of a wildlife sanctuary or national parks (under the Wildlife Protection Act and Biological Diversity Act) (Government of India, 2006; Government of India, 2016; Energetica India, 2014, SECI, 2018).

3.2. Regulatory context in Brazil

The implementation of new-generation solar PV plants generally requires a permit or license. These licenses are prepared by public agencies such as the federal environmental licensing body (Brazilian Institute of Environment and Renewable Natural Resources, IBAMA), environmental licensing state agencies, and intervening agencies.[3] The developer must present the project and its environmental assessment to obtain licenses for the location, construction, and operation of the solar PV plant. In Brazil, environmental studies, such as the EIS, are part of the environmental licensing process; thus, an EIA is required for the project (Bastos, 2010).

Other instruments can be used to conduct an environmental assessment, including strategic tools related to EIA optimization. The Strategic Environmental Assessment (SEA) is a set of tools that aims to provide decision-makers with a broader understanding of the environmental and social implications of their projects. The SEA aims to facilitate environmental integration, and assesses the opportunities and risks that specific actions may present to sustainable development (Partidário, 2012; Thérivel and Brown, 2012). The SEA can significantly contribute to the development of an environmental and sustainable decision-making process that can be applied in Brazilian energy-sector planning (Hoffmann and Cardoso Jr., 2018).

Other planning tools can enhance the quality and extend the applicability of environmental studies and energy-sector licensing. One such instrument is Ecological Economic Zoning (ZEE). This instrument aims to achieve sustainable development by making socioeconomic development compatible with environmental protection in each land unit, and by establishing actions to mitigate or reverse the environmental impact (MMA, 2019).

At the federal level in Brazil, Law 6938/81 and CONAMA Resolution 01/86 (among other regulations) regulate environmental licensing. These laws state that activities that generate electrical power from a source (i.e., hydro, thermal, wind, solar, or other), and have a generation capacity above 10 MW, are subject to environmental licensing.

CONAMA Resolution 279/2001 was published in 2001 as the main legal framework for the environmental regulation of renewable energy. To increase the speed of the process, a simplified, fast-track environmental licensing process was established for applicability to projects that generate electricity, of any capacity, with low environmental impact; this includes transmission lines, hydropower, thermoelectricity, and other alternative sources of electricity (i.e., solar, wind, and biomass) (Brazil. CONAMA Resolution 279, 2001). However, the CONAMA 279/2001 does not establish whether a project has a low impact on the environment.

Considering that solar PV generation plants are specific projects and their locations are flexible, an appropriate area can be selected without having to adhere to the aforementioned mandates. It is therefore unlikely that licensing for this type of activity will be federally regulated. Thus, with the exception of the CONAMA Resolutions 01/1986 and 279/2001, there is no federal regulation that specifically applies to the generation of solar energy (Brazil, 1981, 1986, 2001, 2011).

As defined by Complementary Law 140/2011, a competent body is responsible for permits. This federal legislation defines the licensing for activities (i) on international boundaries, (ii) in more than one state, (iii) that will affect indigenous lands, or (iv) planned for federally protected environmental areas. If these conditions do not apply to the project under evaluation, state regulation for environmental licensing will most likely be approved.

In general, the states define the types of environmental studies required based on the following considerations: the size of the project/plant, the possibility of pollution, and the environmental impact and possible adverse effects. Considering this, the states of Bahia, Goiás, Minas Gerais, São Paulo, and Paraná have been selected to be the states that establish the criteria for state environmental licensing for solar PV plants.

In the states of Bahia and Goiás, one major consideration is the basis for determining which type of environmental study will be applied; however, in Minas Gerais, São Paulo, and Paraná, the most important consideration is the solar PV plant's installed power (Bahia, 2006, 2011, 2012a,b, 2016, Bahia. Decree Nº. 18.218, 2018; Goiás, 2017; Minas Gerais, 2017; Paraná, 2017; São Paulo, 2017).

São Paulo and Paraná have already established assessment criteria to define the typology for environmental studies, and therefore guide and improve the permitting processes for solar PV projects, even though these states are not among those with higher levels of solar irradiance (Paraná, 2017; São Paulo, 2017).

The states of Piauí, Ceará, Rio Grande do Norte, and Rio de Janeiro are still developing regulations for their permitting processes. In general, these states only base regulatory decisions on the size of the project and possibility of pollution. They have not yet developed specific requirements for the environmental licensing of solar PV-based projects.

Some activities that are subject to specific mandates in the state of Piauí can be conducted as simplified studies, only requiring a Simplified Environmental Report, or an Environmental Impact Study (for more complete studies); however, these activities do not include electricity-generating projects (Piauí, 1996, 2009, 2017).

In Ceará, an ordinary license is required for most projects, with the exception of micro-sized projects with a low environmental impact. In these cases, only a simplified license is required. State legislation defines the impact of solar PV projects as “moderate,” and classifies the size of the projects according to the generation capacity of the relevant plant. However, this legislation does not explicitly state which environmental study classification is applicable to these types of projects (Ceará, 1987, 2011, Ceará. Law 14, 2011, Ceará. COEMA Resolution Nº 10, 2011).

Legislation for the state of Rio Grande do Norte states that activities with a significant environmental impact require an EIS. The relevant agency, i.e., the Rio Grande do Norte Institute for Sustainable Environmental Development (IDEMA), is responsible for determining whether non-simplified studies are necessary for the licensing process. A simplified license is applied to projects with a low risk for pollution. Solar energy-based power generation is classified as low risk, and its size is classified as either micro or special case, according to its installed generation capacity. However, legislation does not define the type of environmental study that is applicable to each type of project (Rio Grande do Norte, 2006, 2009, 2011a; b, 2014).

Legislation for the state of Rio de Janeiro defines the categories of environmental impact according to project size and its potential for pollution; however, it does not determine the type of environmental study required for each case. Furthermore, the legislation does not classify solar energy-based power generation projects (Rio de Janeiro, 2012, 2014, 2015).

Regulation for the licensing of solar PV projects is still in its initial stages in the state of Paraiba, which is an area that is well suited for

[3] Intervening agencies: these agencies are responsible for environmental licensing specificities; for example, FUNAI, which focuses on Indians, the Palmares Cultural Foundation, which focuses on traditional *Quilombolas* communities, IPHAN, which has themes that are related to the defense of archaeological, tangible and intangible assets, and the Brazilian Ministry of Health, which is responsible for topics related to the prevention of endemic diseases such as malaria.

solar PV generation. General information on state environmental licensing is available on the environmental agency's website. However, the official state legislation that regulates the licensing process, and information about the activities, are not available. In a consultation with the state environmental agency, it was mentioned that determination of the appropriate type of environmental study is based on the CONAMA 279/01 (SUDEMA, 2018).

3.2.1. Examples in Brazil

To productively contribute to the discussion on Brazilian environmental licensing, the following five case studies were included in the article. Unfortunately, as affirmed by Silva (2019), there are not many EIS reports on utility-scale solar PVs in Brazil.

1. Solar PV Complex "**Bom Lugar Norte Icó**" – located in the state of Ceará, occupies an area of 455 ha, and has an installed capacity of 217 MW. The environmental permitting process was conducted by the State Superintendent of the Environment (SEMACE), and an EIA was prepared in 2018;
2. Solar-Wind Complex "**Serra da Babilônia**" – located in the state of Bahia, occupies an area of 594 ha, and has an installed capacity of 152 MW. The environmental permitting process was conducted by the relevant state agency, i.e., the Institute of Environmental and Water Resources (INEMA), and an EIA was prepared in 2018;
3. Solar Park "**Nova Olinda**" – located in the state of Piauí, and operations began in 2018; its installed capacity is 290 MW. The environmental permitting process was conducted by the State Secretary for the Environment and Water Resources (SEMAR), and an EIA was prepared in 2016;
4. Solar Park "**Pirapora**" – located in the state of Minas Gerais, has an operating capacity of 240 MW, and occupies an area of approximately 800 ha. The environmental permitting process was conducted by the State Secretary for the Environment and Sustainable Development (SEMAD); a study equivalent to the EIA was prepared in 2016;
5. Solar PV Complex "**Malta**" – located in the state of Paraíba, has an operating capacity of 55 MW, and occupies an area of approximately 120 ha. The environmental permitting process was conducted by the State Superintendent for Environmental Administration (SUDEMA), and a simplified environmental report was prepared in 2014.

An EIS was also prepared for a smaller solar PV plant: the Tauá Photovoltaic Solar Generating Center. Located in the state of Piauí, this plant has 50 MW of installed capacity and occupies an area of 203 ha; it was subjected to an EIS in 2011. The Tauá PV plant is the first functioning PV plant in Brazil.

Fig. 3 shows a map of Brazil that was constructed as based on data from the Brazilian Atlas of Solar Energy, data on projects currently in operation, data on case study projects, and data on Brazilian states with well-defined legislation for the environmental licensing of solar PV projects.

4. Discussion

The results show that there is no significant difference between the environmental licensing processes of the analyzed countries. Most of them use formats that include comprehensive environmental impact studies and a simplified study. The general tendency in these countries is to assess projects on a case-by-case basis to determine the appropriate level of detail required for the environmental study.

The exceptions are Portugal and Spain, where the federal legislation does not establish a simplified framework for environmental permits. This is because, in most countries, only projects with a higher likelihood of significant environmental impact are analyzed by the relevant federal agency. These projects would probably require a complete EIS.

Canada and Australia have policies similar to those of Brazil regarding the environmental licensing of renewable energy projects; this means that there is no specific federal legislation for this type of project, and that the regulations differ among provinces and regions. This trend towards the decentralization of licensing may be related to the size of each of the countries, and their environmental and socioeconomic diversity. However, countries with similar dimensions (size) and diversity, such as China and the United States, apply a centralized licensing model. The differences among these countries could be explained by considering the selected strategy of each country. Canada and Australia promote a very specific and detailed process that is customized for each region and its singularities; conversely, China and the United States may have established a centralized process to promote a standardized permitting and implementation process for solar PV projects.

In Brazil, the only applicable legislation for federal permits for solar PV projects is the CONAMA Resolution 279/2001, but this regulation does not discuss specific environmental considerations that define whether the project has a high or low likelihood of significant environmental impact. Note that this current regulation was established in 2001, before environmental assessment criteria for the construction and operation of solar PV projects had been discussed. Because the environmental considerations are not explicitly defined, each case may be subjectively interpreted, and the permitting process for solar PV projects may therefore be inadequate and inconsistent.

At the state level, Bahia, Goiás, Minas Gerais, São Paulo, and Paraná have well established regulations for the permitting process for solar PV projects. The first three states are located in an area that is well suited for solar generation, as shown in Fig. 3. Although São Paulo and Paraná are not as well suited for solar generation, they have also regulated the licensing process, being motivated by the need to generate centers near consumers. It should be noted that these states only recently established regulations; specifically, the regulations were developed in 2017 in response to the interest in solar energy utilization in the energy sector.

States with high potential for solar PV generation are still in the process of establishing regulations for environmental permits for solar PV projects. The legislation for Piauí, Ceará, and Rio Grande do Norte provides information about the licensing process; however, the legislation does not establish the need for any specific environmental study. The legislation for the environmental permitting process in Paraíba, which is one of the states with the highest potential for solar PV, is not accessible to the public; thus, information about the case study was obtained by submitting an official inquiry to the environmental agency.

The American Solar PEIS (Solar Energy Development Programmatic EIS, 2018), which was performed in the region of the United States with the highest solar PV generation potential, is noteworthy because a comprehensive environmental assessment was established to guide the evaluation process and implementation of solar energy projects. In Brazil, this scenario is quite different. Unfortunately, the states with the highest potential are those that do not yet have specific regulations for the licensing of solar PV plants, making the development process quite subjective and inconsistent, varying according to the environmental agency.

Based on the Brazilian case studies, it was possible to determine that state environmental agencies require an EIS for solar PV plants with an installed capacity between 50 and 290 MW, and area between 120 and 800 ha. These wide ranges for the installed capacity and area complicate standardization. The discussion on these cases could be improved by including the critical paths of the processes, their respective durations, and the costs associated with obtaining an environmental permit. However, this information is not available, as well as several EIS reports for utility-scale solar PVs in Brazil.

The uncertainties associated with the absence of specific and accessible regulations may generate insecurity in potential investors, and thus lead to decreased investments since the time and costs associated with obtaining an environmental permit cannot be reasonably predicted. This insecurity also causes the costs associated with mitigating

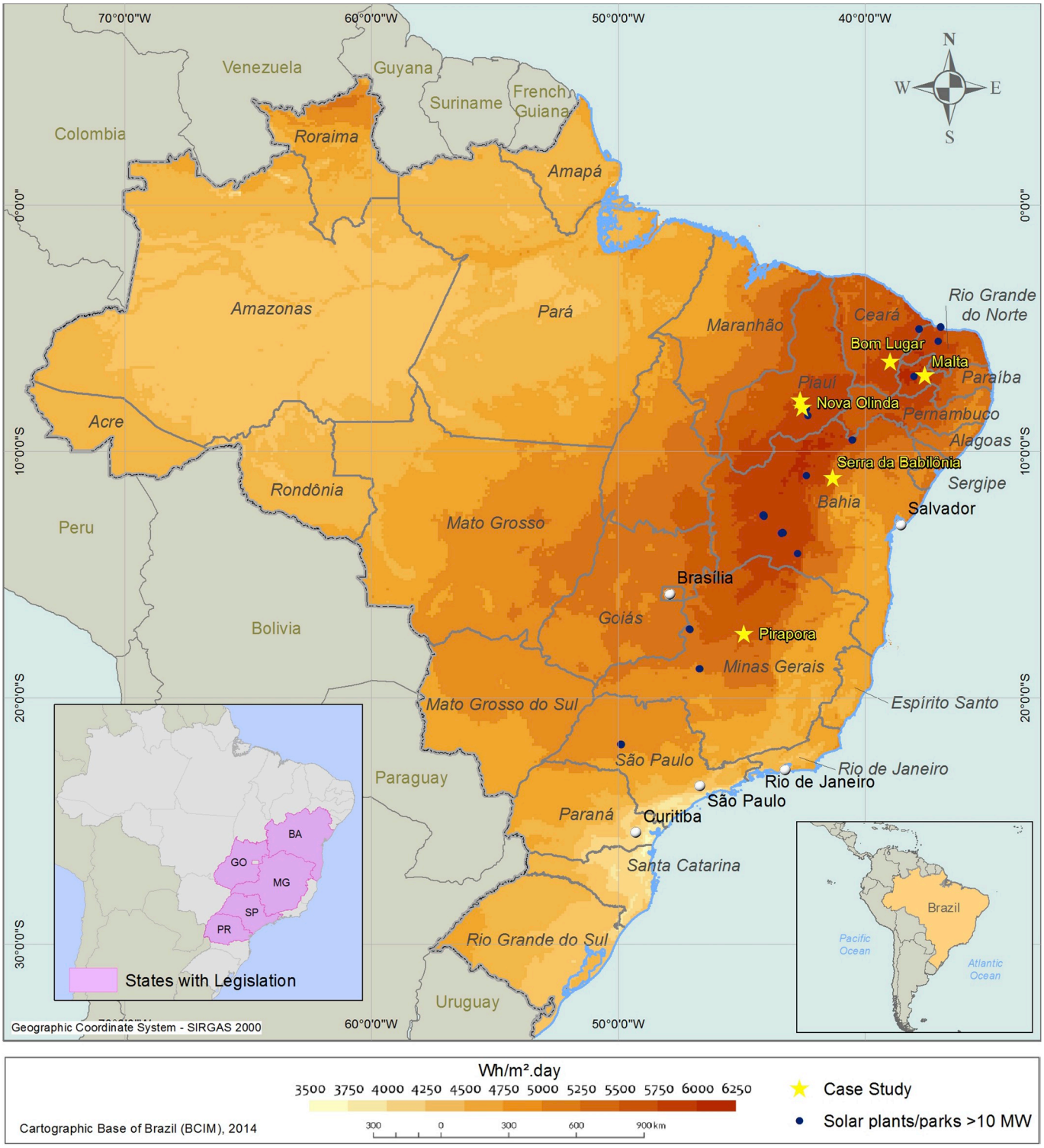

Fig. 3. Map showing total daily solar irradiance in Brazil; it includes data from projects currently in operation, and solar PV project case studies.

risks incurred by new investors to increase, which consequently results in an energy price increase for consumers.

There is an obvious lack of synergy and incompatibility between environmental licensing and other public environmental planning and management instruments, such as Ecological Economic Zoning (ZEE), Coastal Economic and Ecological Zoning (ZEEC), and Strategic Environmental Assessment (SEA). Indeed, there is significant potential and demand for SEA application in the solar-power generation sector in Brazil, as it would allow priority areas, in which solar PV plants would result in a relatively lower environmental impact, to be mapped and established. The absence of a SEA hinders the development of a more comprehensive environmental licensing policy.

5. Conclusions and policy implications

Based on the assessment of the results of this work, it was possible to identify the main challenges associated with the permitting process for solar energy-based projects in Brazil, especially those related to

Table 1
Summary of international legislation and framework.

Country	Legal instruments	Criteria	Possible frameworks cited on legislation	Comment
United States	National Environmental Policy Act, 1969	Area	Categorical Exclusion (CATEX) Finding of No Significant Impact (FONSI) Environmental Impact Statement (EIS)	A joint EIS was performed in six southwestern US states, identifying priority areas for solar PV projects with lower potential for conflict.
Canada	Canadian Environmental Assessment Act (2012); State legislation also applied	Regional considerations	Standard Environmental Analysis Review Panel Analysis	Environmental permitting for renewable energy projects is performed by the provinces at a regional level.
China	Environmental Protection Law of the People's Republic of China (1989); Law of the People's Republic of China for Environmental Impact Assessment (2003)	Discharge pollutants Environmentally sensitive areas	Environmental Impact Registration Form Environmental Impact Report (EIR) Form EIR	
European Union	Directive 2011/92/EC	Not specified at EU level	Environmental Impact Assessment (EIA) Case-by-case analysis	The EU states that member countries must assess electrical energy generation projects on a case-by-case basis, and individually establish the need for an EIA.
Portugal	Law 151-B/2013	Installed capacity Environmentally sensitive areas	Environmental Impact Study	Legislation does not establish a simplified framework for environmental permits.
Spain (Balearic Islands)	Law 11/2006	Installed capacity Environmentally sensitive areas	Environmental Impact Study	The legislation does not establish a simplified framework for environmental permits.
Germany	Law *UVPG* 1990 Local legislation also applied	Local environmental considerations Alignment with local zoning	Simplified permit	Municipalities establish priority areas for solar PV plants (zoning), and a simplified permit is prepared.
Australia	Environment Protection and Biodiversity Conservation (EPBC) Act; State and local legislation also applied	World Heritage and national heritage sites Wetlands Habitats of threatened or migratory species Federal marine areas Nuclear sites	Not specified at federal level	Licenses and permits can be issued by state or local governments if the environmental impact is local.
India	Environmental Impact Assessment (EIA) Notification (2006)	Forested areas Wildlife Sanctuary National Parks	Exemption from environmental permits	Because renewable energy projects yield insignificant long-term adverse impacts on the environment, they do not require environmental permits.
Brazil	Law 6938/81; CONAMA Res. 01/86; CONAMA Res. 279/2001; Complementary Law 140/2011; State legislation also applied	Not specified at federal level	Not specified at federal level	The environmental permitting process for solar PV projects is determined by the states.

Table 2
Summary of federal and state legislation and relevant frameworks in Brazil.

State	Legal instruments	Criteria	Possible frameworks cited on legislation	Comment
Bahia	Decree 14.024/2012	Small (up to 50 ha)	Environmental Impact Study for Low Impact Activity (EPI); Unified License (LU)	Study definition is dependent on project scale (required area in ha). There is the possibility of a joint permit for similar projects in the same vicinity as long as the legally responsible party for these joint projects and activities has been identified.
	Decree 18.218/2018	Moderate (50 ha–200 ha)	Environmental Impact Study for Low Impact Activity (EPI); Unified License (LU)	
	Law 10.431/2006	Large (over 200 ha)	Environmental Study for Moderate Impact Activity (EMI); Previous License, Installation License, Operation License (LP, LI, and LO)	
Goiás	SECIMA Res. 036/2017	Small (up to 30 ha)	Declaratory	Study definition is dependent on required project area (ha) and impact of the criteria: • Fluvial plains • Suppression of vegetation • Environmentally protected areas and surroundings (up to 3 km) • Routes and areas of concentration of migratory birds • Removal of residing communities • Endangered species or endemism
		Moderate (30 ha–100 ha)	Simplified Environmental Report and Environmental Control Plan (RAS/PCA); Previous License, Installation License, Operation License (LP, LI, and LO)	
		Large (over 100 ha)	Environmental Impact Study/Environmental Impact Report (EIA/RIMA); Previous License, Installation License, Operation License (LP, LI, and LO)	
Minas Gerais	COPAM Res. 217/2017	Small (5–10 MW) Moderate (10–80 MW) Large (over 80 MW)	Declaratory: only applied to small-scale projects with no inference in any determining location-selection criteria; OR Simplified: require a Simplified Environmental Report (RAS), and a Simplified License is subsequently issued; OR Concurrent (1 or 2): the Previous License, Installation License, and Operation License may be issued in one or two phases.	Study definition is dependent on project scale (in MW) and impact of the criteria: • Environmentally protected areas and their surroundings • Suppression of native vegetation • Ramsar archaeological sites • Ecological corridors • Specially classified water bodies • Conflict with supply water • Areas with high or very high potential for caves
São Paulo	SMA Res. 74/2017	Small (Up to 5 MW)	Only an authorization for suppression of native vegetation or installation in flood protection areas is required, if necessary.	Environmental impact potential is not established. Study definition is dependent on project scale (in MW) and impact of the criteria: • Environmentally protected areas and their surroundings • Suppression of native vegetation • Removal of residing communities • Areas of scientific, cultural, historical, archaeological, or speleological interest
		Moderate (5 MW a 90 MW)	Simplified Environmental Study, EAS; Previous License, Installation License, Operation License (LP, LI, and LO)	
		Large (Over 90 MW)	Preliminary Environmental Report, RAP; Previous License, Installation License, Operation License (LP, LI, and LO)	
Paraná	IAP Res. 19/2017	Up to 1 MW	Exemption from environmental licensing	Environmental impact potential is not established. Study definition is dependent on project scale (in MW) and impact of the criteria: • Suppression of vegetation • Environmentally protected areas and surroundings (up to 3 km) • Endangered species or endemism • Demands transfer of more than 100 m^3 of soil
		Small (1 MW–5 MW)	Environmental authorization or exemption from environmental licensing upon presentation of a memorandum describing the project	
		Moderate (5 MW–10 MW)	Simplified Environmental Report, RAS; Previous License, Installation License, Operation License (LP, LI, and LO);	
		Large (Over 10 MW)	Environmental Impact Study/EIR (EIA/RIMA); Previous License, Installation License, Operation License (LP, LI, and LO)	
Piauí	Law 4.854/1996	Not specified	Exemption from environmental licensing for small-scale projects with low environmental impact potential	Power generation is not mentioned in state legislation for permits; neither the scale nor the environmental impact potential of this activity is established.
	CONSEMA Res. 10/2009		Simplified Environmental Report, RAS; Previous License, Installation and Operation License (LP, LIO)	The required environmental study is not established. Specific criteria are not specified.
	Law 6.947/2017		Environmental Controle Plan, PCA Environmental Impact Study/EIR (EIA/RIMA); Previous License, Installation License, Operation License (LP, LI, and LO)	
Ceará	Law 11.411/1987 Law 14.882/2011 COEMA Res. 10/2015	Small (Up to 5 MW) Moderate (5 MW–15 MW) Large (15 MW–50 MW) Exceptional (Over 50 MW)	Previous License, Installation License and Operation License (LP, LI, and LO); Environmental study not established	Solar PV generation is mentioned in the state legislation, which includes definitions of the scale and environmental impact potential. The required environmental study is not established. Specific criteria are not specified.

(*continued on next page*)

Table 2 (*continued*)

State	Legal instruments	Criteria	Possible frameworks cited on legislation	Comment
Rio Grande do Norte	Law nº 272/2012 CONEMA Res. 04/2006 CONEMA Res. 04/2009 CONEMA Res. 04/2011 CONEMA Res. 02/2014	Micro (Up to 5 MW) Small (5 MW–15 MW) Moderate (15 MW–45 MW) Large (45 MW–135 MW) Exceptional (Over 135 MW)	Simplified License (LS); Environmental study not established	Solar PV generation is mentioned in the state legislation, which includes definitions of the scale and potential environmental impact. The required environmental study is not established. Specific criteria are not specified.
Rio de Janeiro	CONEMA Res. 42/2011 Decree Nº 44.820/2014 Decree Nº 45.482/2015	Not specified	Simplified Environmental Report, RAS; Simplified License (LAS) Environmental Impact Study/EIR (EIA/RIMA); Previous License, Installation License, Operation License (LP, LI, and LO)	Power generation is not mentioned in state legislation for permits; neither the scale nor the environmental impact potential of this activity is established. The required environmental study is not established. Specific criteria are not specified.
Paraíba	Unavailable	Not specified	Not specified at state level	The requirements for environmental permits are not available.

specifying the appropriate environmental study based on the relevant legislation.

The lack of accessible data regarding the details of the environmental permitting process and studies developed for existent solar PV plants in Brazil not only limits this type of research, but also new project development. The absence of information regarding the main guidelines and challenges critically affects the permitting process, the decision of potential investors, and thus the future of PV projects in Brazil.

The inconsistent criteria and low accessibility of accurate information result in the relevant environmental agency making subjective decisions. The current development of these studies could hinder the implementation of projects, sometimes even failing to prevent or minimize the environmental impact; this would thus result in the desired objectives, i.e., the advisable level of environmental protection, not being achieved.

The criteria for defining the environmental studies vary according to the environmental agency, especially in the states with the highest potential for the implementation of these projects, and are related to the size of Brazil, which still has a diverse and preserved biotic and abiotic environments that must be taken into consideration. The major considerations for regulating the licensing process for solar PV generation projects in Brazilian states are the area and installed capacity of the plant. The sanctuaries of migratory birds and other areas protected by specific legislation are also considered in the permitting process.

The criteria for the permit process, which varies according to the Brazilian state, require specific knowledge about current regulations. To overcome these obstacles, it is important to develop federal guidelines that will provide the necessary support for the states to define more coherent and consistent criteria.

By adopting such measures, a licensing process that takes into account the singular environmental considerations and restrictions of each region can be developed; this would allow the permitting process to be optimized, and prevent all significant obstacles to securing the investments needed to increase solar power generation in Brazil.

It is also highly recommended that the Brazilian government, including environmental agencies and other public actors, prepare a SEA to promote solar PV generation while minimizing its social and environmental impact.

Appendix

Table 1 presents a summary of international environmental legislation that is applicable to solar PV projects, and Table 2 presents a summary of the state environmental legislation that is applicable to solar PV projects in various states of Brazil.

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