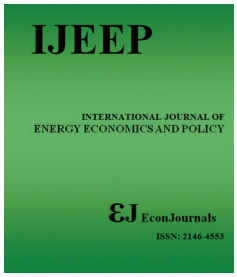

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Diagnosis of the Energy Regulatory Scenario with Emphasis on Smart Energy

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ABSTRACT

The energy management system has evolved into a digitized and autonomous environment, where consumers can manage their own generation, consumption and storage through virtual environments. Smart Energy (SE) understands this decentralized energy management by streamlining and helping in this matter, however, there is a need to regulate this scenario. Considering that the electric energy sector has a solid regulation, efforts need to be concentrated to adapt it to a model that emphasizes the SE and everything that it proposes. Therefore, the objective of this article is to propose a diagnosis of the current energy regulatory scenario directed to the SE. Through a focus group, experts from the energy sector contributed with opinions on the subject for the construction of a Current Reality Tree (CRT), which aimed to identify the root causes that affect and limit the energy regulation scenario SE-oriented. The current situation of this scenario was analyzed and what can be changed. 38 actions that contribute to the development and propagation of SE were suggested. These actions are guiding ways to regulate and enable the regulatory environment to support the insertion of technologies related to the theme.

Keywords: Smart Energy, Energy Cloud, Energy Regulation, Current Reality Tree
JEL Classifications: Q42, K32, P28, P48

1. INTRODUCTION

Insufficient energy production causes cuts, while overproduction generates unnecessary expenses that lead to environmental problems (Kim and Cho, 2021), and problems such as energy crisis and environmental pollution are increasingly serious (Quan et al., 2021). Therefore, the smart grid, together with the internet, provides a fusion of production, market, consumption and transmission of energy (Renugadevi et al., 2021), and it becomes necessary to adopt new computational technologies to manage this increasingly dynamic market (Schaefer et al., 2021). Cloud-based energy management system combines the smart grid with the concepts of Cloud Computing (CC), which serves to store, monitor and control data remotely (Kulkarni et al., 2019). This system has different terminologies. Some authors conceptualize it as Energy Cloud (Giordano et al., 2019) (Stefan De Carvalho et al., 2022), others as Internet of Energy (Fang et al., 2020) (Zhang et al., 2022), also it can be called Energy Hub (Esapour et al., 2022) (Alnowibet et al., 2021), or Transactive Energy (Zamani et al., 2022). The most popular term that will be used in this article is Smart Energy (Morelli et al., 2022) (Tronchin et al., 2018).

(Parvin et al., 2022) refer to this model as an intelligent system that provides access, control and transmission of data applications,

decision support, remote control, monitoring of consumption and energy generation and storage systems. Data is stored on the cloud server and energy devices are integrated into a storage network, where data can be accessed by devices, assisting in energy management through the analysis of consumption history (Renugadevi et al., 2021). In the SE, interested parties can interact without supervision or third-party intervention, and sellers and buyers trade freely through a platform (Ben Abdeljawed and Amraoui, 2021). The evolution of traditional energy systems to SE can occur through the interconnection of users with the distribution network (Giordano et al., 2019).(Giordano et al., 2019).

The technologies involved must be accessible to all energy users, not just those with higher incomes or education. Considering that the use of renewable energy would increase if policy incentives covered part of the cost of maintaining and installing renewable energy users (Okwanya et al., 2020), there is also the fact that funding for new infrastructure (such as electrical wiring and high-speed internet installation) is limited, and approvals can take years for new infrastructure projects (Saidani Neffati et al., 2021). In view of this, there are several factors that interfere with the development and evolution of SE, such as economic factors (Bento et al., 2020), social or socioeconomic factors (Okwanya et al., 2020), availability factors (Iwaro and Mwasha, 2010), institutional or market factors (Frate and Brannstrom, 2017), de infraestrutura regulatória (Jackson Inderberg et al., 2020), external and information factors (Armstrong, 2019), and also ideological factors (Pereira Bastos and de Macedo-Soares, 2011). For this technological integration due to the expansion of Distributed Energy Resources (DER) of renewable energy to happen equally among users, it is necessary to adapt and/or implement regulatory aspects that are different from conventional ones (Carvalho et al., 2021) and that include the aforementioned factors.

In this sense, it is necessary to understand how the regulatory scenario works by identifying the steps and decisions that interfere in the transition to SE-based energy management. The Current Reality Tree (CRT) is a tool that helps to identify basic problems in a system, and can be used in the context of energy regulation. CRT uses cause and effect logic to create a map of the existing situation and precisely identify the basic problem, which is the common cause of several undesirable effects (UDEs), and thus it is possible to concentrate efforts on this problem (COX III; SCHLEIER, 2013). From its construction, it becomes possible to develop action plans focused on solving these problems, making it possible to analyze the situation of the system and what its basic problem is, analyzing what can be changed. The use of CRT in the context of regulation of the energy sector contributes to the proposition of identifying the root causes that affect this ecosystem. These root causes result in UDEs, which limit the development and propagation of renewable energies directed to the decentralized and autonomous environment of the SE. The characterization of these basic causes allows the elaboration of a diagnosis that identifies the UDEs that delay this scenario, making it possible to develop action plans.

Therefore, the objective of this article is to propose a diagnosis with propositions of guiding actions for the current energy regulatory scenario directed towards Smart Energy. For this, experts in the energy area were interviewed using a research instrument in order to collect opinions about factors that interfere in the regulatory scenario (economic, personal, availability, institutional and market factors, regulatory infrastructure, factors external and information, and embedded ideology of regulation). The novelty of this research lies in the presentation of guiding actions to regulate and empower the regulatory environment to support the integration of technologies related to the subject, with potential for use in any country undergoing an energy transition. This research aims to bring important contributions such as:

- Presentation of a systemic view of the problems encountered in the energy regulatory scenario with an emphasis on SE.
- Schematization of cause and effect relationships, where it is possible to examine the main problems that delay the development of SE.
- Identification of root causes, intermediate effects and main effects of SE regulation.
- By identifying the UDEs, this research contributes with the presentation of a diagnosis of the energy regulatory scenario, through the analysis of what must be changed so as not to cause delays in the development and evolution of the SE.

The article is organized into 6 sections: Section 2 presents a theoretical framework on SE and the regulatory scenario. Section 3 contemplates the methodological procedure used. Section 4 brings the results and discussions and section 5 addresses the conclusions and contributions of this research.

2. SMART ENERGY AND REGULATION OF THE ENERGY SECTOR

The main objective of SE is to provide a reliable, secure and cost-effective service to industry stakeholders, but decentralized management and control of this system are major challenges (Jararweh, 2020). Among the challenges, it can be mentioned the optimization of energy consumption (Liu et al., 2019), efficient management of distributed energy resources in micro-grids, homes, buildings, smart grids and smart cities (Al Faruque and Vatanparvar, 2016), in addition to greater dissemination of renewable energies to diversify sources and reduce the intermittency of generation, integrate physical infrastructures with technologies and computational systems, guarantees of security and privacy of data and user information, among others.

(Schaefer et al., 2020) identified the layers necessary for the operation of this system. Here comes the Physical layer, which corresponds to the physical facilities for generation, distribution, storage and energy consumption, the Fog layer, which aggregates the data and prepares it for sending to the cloud, the Network layer, responsible for the connection between the user's system with the data cloud. Cloud layer, which stores and prepares the data for processing that takes place in the Service layer. The Session layer, which takes the Service's data to the Application's management applications. In addition to the Broker layer that assists the energy market, Security and Privacy, Third-Party Services and Cloud Auditor. Therefore, another challenge is how this system and the areas involved in its operation will be regulated.

To achieve the objectives of the SE, policymakers need greater agility in establishing and adapting regulatory aspects, due to the rapid advancement of energy systems through the integration of computational technologies (Schaefer et al., 2020). Therefore, new economic models and regulatory tools are needed to address the challenges brought by large-scale renewable energies in smart grids (Song et al., 2022). Updates to energy regulations and policies are necessary as the SE ecosystem will need to be supported by appropriate regulations and policies that define the interaction between utilities, distributed energy resources, and consumers (Jararweh, 2020). When it comes to implementing energy policies, developing countries face challenges, and the cost of the involved technologies is one of the major obstacles (Adly and El-Khouly, 2022).

Energy regulators need to establish policies to promote advanced and efficient technology, directing the actors involved to achieve social goals, through the formulation of appropriate policies according to stakeholder status and constraints (Archana et al., 2022). For the authors, when converting the electrical grid into an intelligent grid capable of increasing productivity, scalability and security, it is essential to understand what the users' restrictions are. It is necessary to adapt energy access policies to the financial and technological context of a given context, and to assess whether the implementing agency itself has the financial, technological and human skills necessary for implementation (Bhanot and Jha, 2012). Thus, it is possible to adjust the policies already in their conception to be aligned with the needs and capacities of the region of implementation.

The regulatory paradigm of energy aims to establish the guidelines, rules, and mechanisms necessary for granting licenses, defining tariffs, regulating service quality, protecting consumers, monitoring and overseeing the energy sector, among other activities. Its purpose is to ensure a balance between the interests of various stakeholders involved, such as energy suppliers, distributors, consumers, and the government. Regulatory aspects and public policies have a positive and significant impact in promoting the development of a cleaner and decentralized energy landscape and can be drivers of the SE.

3. METHODS

The methodology is organized in three stages. The first is the development of a research instrument to collect information from specialists about the energy regulatory scenario with a focus on SE. The second stage includes the construction of the CRT based on the experts' statements obtained in the first stage. The third stage comprises the focus group technique, with the objective of discussing the validation of the CRT.

3.1. Research Instrument

Semi-structured interviews allow flexibility for the interviewee to provide their individual perspective and create opportunities for new ideas, being an approach that includes an interview guide that can have targeted and open questions (Aikenhead et al., 2015). The survey instrument questions were organized according to the following factors: Economic/socioeconomic factors, personal or sociocultural factors, personal or socioeconomic factors, availability factors, institutional and market factors, regulatory infrastructure factors, external and information, and ideological factors embedded in regulation. The research instrument had the objective of collecting information about the undesirable effects regarding the scenario of regulation of the electric energy sector for later construction of the CRT.

This research instrument was conducted through a questionnaire containing 23 open questions, structured through the Google Forms research management application and was applied to different actors in the energy system, such as regulatory specialists, researchers, representatives of energy service providers, services in the area of energy and data cloud and members of regulatory agency or association of energy companies. 21 experts responded to the survey, 2 from India, 1 from Pakistan, 1 from South Africa, 2 from the United States, and 15 from Brazil. The research instrument is available in Appendix A.

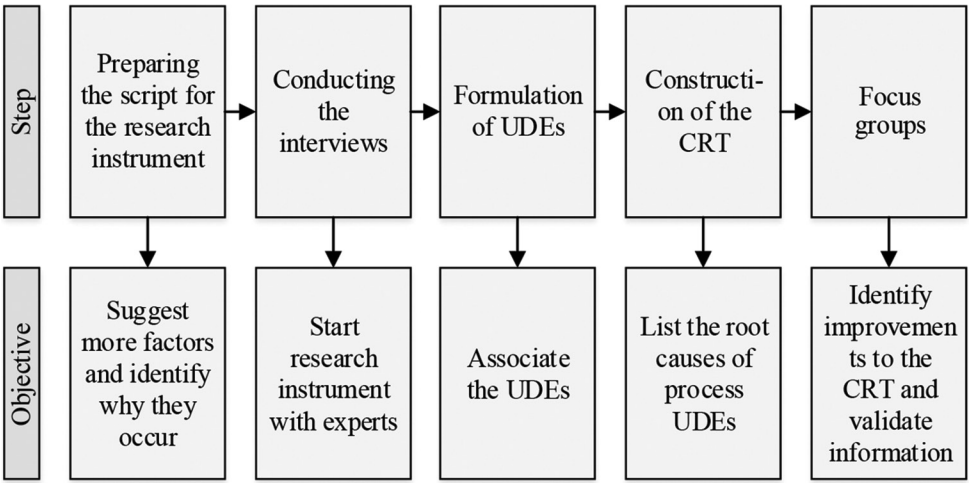
3.2. Construction of the Current Reality Tree (CRT)

Figure 1 contemplates the steps followed in this research for the elaboration and construction of the CRT, following the steps described by (Noreen et al., 1995) and (Rahman, 2002).

The research instrument was elaborated considering factors that interfere in SE regulation, so that specialists could suggest more factors. Experts were selected through LinkedIn for an interview process, where they were asked to talk about the problems they experience in their professional lives (COX III; SCHLEIER, 2013). The Theory of Constraints (TOC) is a systemic approach aimed at problem-solving. Therefore, the Thinking Process of the theory of constraints and TOC allows for a better visualization of processes, a systemic view of the problems encountered in the processes, and consequently, an improved redesign of the processes (Lacerda et al., 2010). The tools of the thought process play an essential role as guides for decision-making and the creation of logical representations, as well as problem structuring instruments. These tools include the Current Reality Tree (CRT), the Cloud Evaporating (CE), and the Future Reality Tree (FRT), among other tools that facilitate efficient implementation (COX III; SCHLEIER, 2013). In this research, only the CRT was used. The CRT identifies and describes cause-and-effect relationships, thereby determining the main problems of a system (COX; BLACKSTONE; SCHLEIER, 2003), providing an overview of the current situation of the company or process (da Costa et al., 2018). Thus, the CRT is primarily applied to answer the question "What to change?," where it possesses cause-and-effect relationships that connect the UDEs (Undesirable Effects) - the aspects of a situation that one desires to improve.

The interviewees' statements were then transformed into UDEs, and the construction of the CRT began with the writing of the logical cause and effect relationship between these UDEs. The cause-and-effect relationships are visually represented with causes positioned at the bottom and consequences at the top of the relationship. In this way, the topmost UDE in the tree is referred to as the main effect since it does not cause any other effect and is usually the effect that people are most aware of or find most

Figure 1: Steps for the elaboration and construction of the CRT



Source: Adaptado de (Noreen et al., 1995) e (Rahman, 2002).

noticeable (González et al., 2017). According to the authors, the EIs located in the middle of the tree are intermediate effects, while the root cause is at the base, from which all other UDEs originate. Therefore, the CRT is useful for identifying the root cause responsible for a multitude of problems in a specific system (Noreen et al., 1995), and it can also be divided into sub-trees to aid understanding (Lowalekar and Ravi, 2017).

The UDEs are then connected through arrows, indicating that the occurrence of one undesirable effect depends on the occurrence of another UDE, which can be either individual or simultaneous with another (Noreen et al., 1995). Thus, the CRT is read in a bottom-up manner, which means that "if cause A exists, then effect B occurs" (Noreen et al., 1995). In the CRT, the primary source of data is words, making it easily incorporate behavioral details, operational issues, policies, and rules. Therefore, it provides a written explanation of the existence of everyday problems and their respective causes (COX III; SCHLEIER, 2013). The last step was the validation of the CRT through focus groups in order to identify improvements.

3.3. Focus Group

The focus group is a form of group interview based on the communication and interaction of previously chosen members, but who do not know each other, with the aim of collecting information and opinions from the group on a certain topic (LOZADA; NUNES, 2018). Focus group discussions are suitable for investigating new topics (Kristensen et al., 2021) and group members must have experience of the phenomenon in different work environments (Tiwari and Khan, 2020). It is important that the construction of the CRT be done with multidisciplinary groups, in order to have an effective communication of the main problems of the organization and a common understanding of these situations (Lacerda et al., 2010). Two focus groups were carried out. The first focus group was composed of 7 experts with experience in different areas of the energy sector and with different positions held, such as regulatory specialists, director of the Brazilian association of wind energy, director of the Brazilian association of photovoltaic energy, research coordinator and market intelligence. The first focus group lasted 2 h.

The experts were free to express their opinion on any issue they found relevant, such as cohesion between the cause and effect relationships of UDEs and the inclusion or exclusion of UDEs, and also suggested actions to improve regulatory issues that delay the development of SE. The second focus group was composed of two researchers from the energy area who have an affinity with SE and lasted 1 h. At that moment, the complete and finalized CRT was presented, and the objective was to validate the tool and verify if the structure was expressing the reality of the energy regulation scenario with an emphasis on SE.

4. RESULTS AND DISCUSSIONS

CRT was built using the Miro digital interactive platform. As a result of this tool, there is a diagnosis of the current energy regulatory scenario, with an emphasis on SE. The CRT can be visualized through Figure 2 and contains 108 UDEs, of which 38 are basic causes or root causes, which are those that do not have entry arrows and are marked with a box in bold. The CRT has the intermediate effects, which are the UDEs with entry and exit arrows, and the main effect is represented by the UDE "1. There is no regulation for Smart Energy," which lacks exit arrows.

The UDEs are differentiated by color, with the lime green color corresponding to "Institutional and market factors," the lilac color to "Personal or sociocultural factors," the pink color to "Ideology embedded in regulation," the green color refers to issues related to "Availability," the salmon color to "External and information factors," the blue color to "Economic/socioeconomic factors," and the orange color refers to "Regulatory infrastructure."

The CRT reading is done from bottom to top (Noreen et al., 1995), and when arrows are connected by an ellipse, it is read as "and." Taking the CRT clipping available in Figure 3 as an example, the reading is done as follows: if "36. There is a lack of R&D projects for the energy area" and if "37. Power company managers sometimes overlook the benefits of other sources of electricity generation," then "35. There is a lack of understanding of the contribution of new technologies to energy management." If "35.

Figure 2: Current reality tree of the current energy regulatory scenario directed towards smart energy

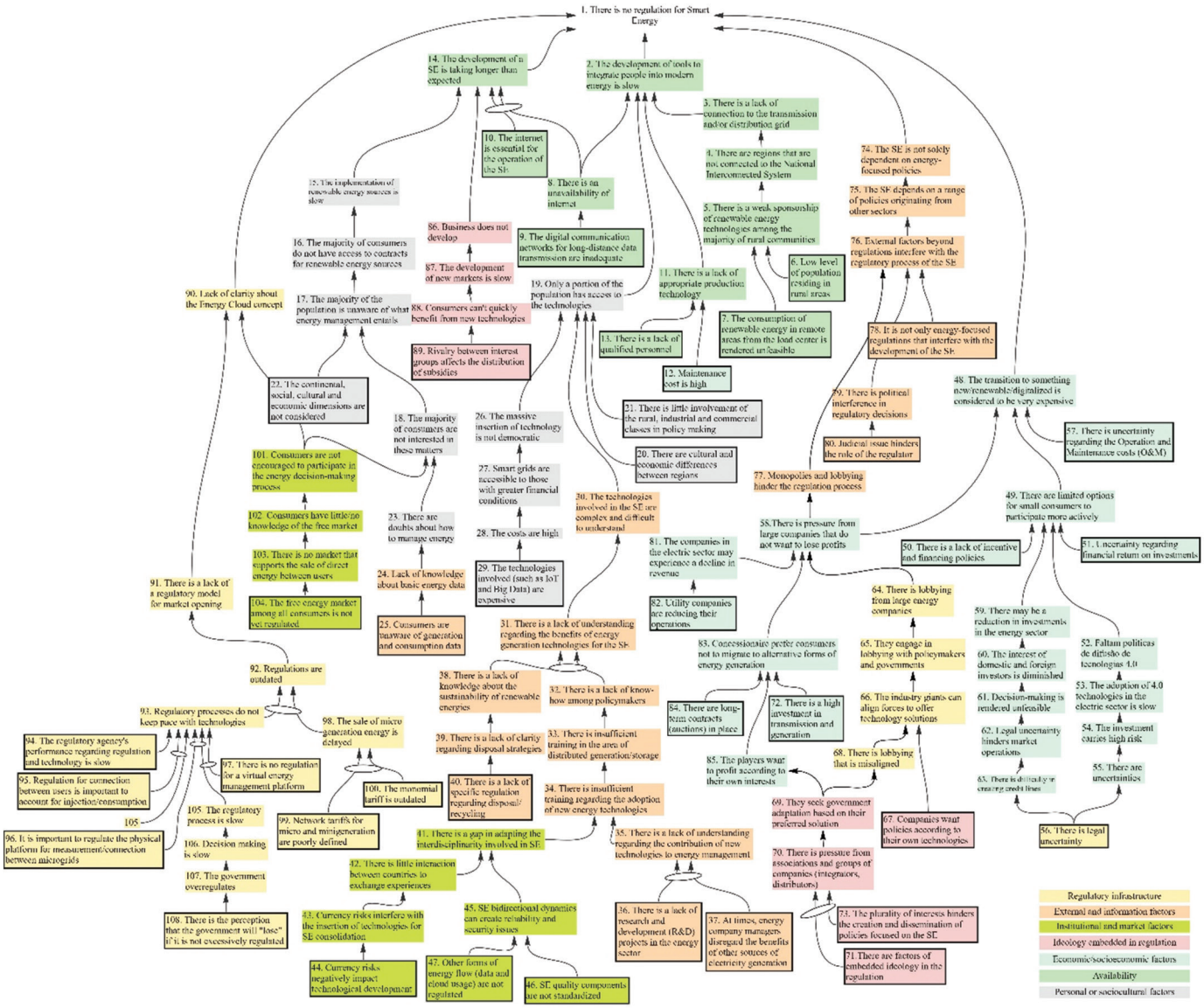
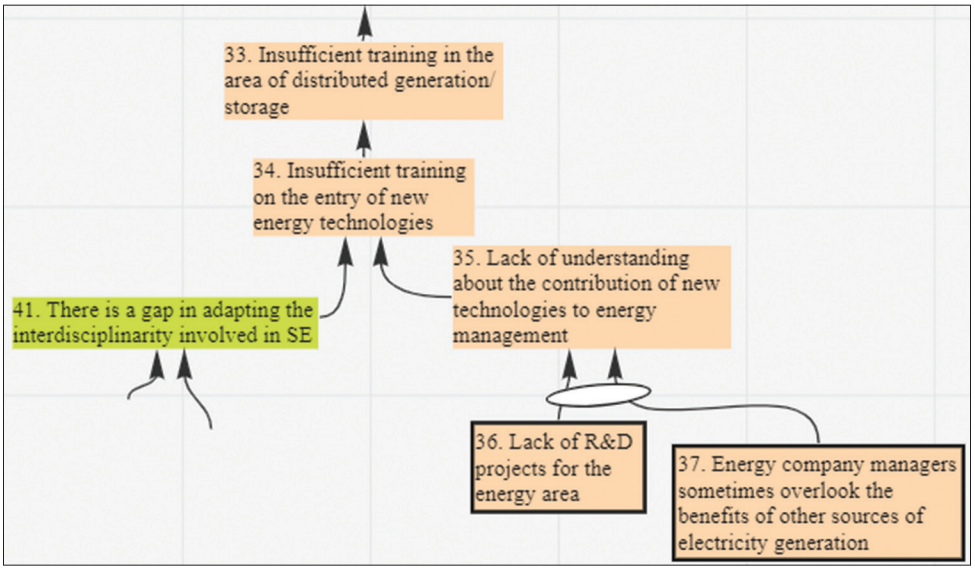


Figure 3: CRT clipping for reading example



Lack of understanding about the contribution of new technologies to energy management" or whether "41. There is a gap in adapting the interdisciplinarity involved in SE," then "34. Insufficient training on the entry of new energy technologies," if 34, then "33. Insufficient training in the area of distributed generation/storage."

According to (da Costa et al., 2018), the main objective of CRT is to identify the root causes, as it is the UDEs that cause all the others, and therefore, improvement actions are focused on these UDEs. Therefore, this section discusses the root causes and the recommended strategies based on them. Thus, it was analyzed what should be changed in the energy regulatory scenario in order not to delay or hinder the development and evolution of the SE.

4.1. Economic/socioeconomic factors

According to the CRT, 7 root causes (Table 1) related to economic/socioeconomic factors were identified. The economic/socioeconomic factors deal with issues of financial support and subsidy policies in relation to investments for own energy generation and issues related to the acquisition of technologies involving the SE.

The root cause "50. There is a lack of incentive and financing policies" is related to the high cost of acquiring the necessary equipment to acquire the technologies for implementing and monitoring the SE. Therefore, the action "Have regulations for subsidies" is suggested with the aim of increasing accessibility to technologies involved in renewable energies and SE, due to the high cost that the transition to this renewable and digitized scenario involves. Along the same lines, it is suggested to "Have a level of support based on production," such as bonus issues for the adoption of clean energy sources, "Have a level of financial support," which are financial subsidies to facilitate the introduction of new technologies and increasing the share of alternative renewable sources in electricity production, and "Have investment-based support level," as the incentives that help expand investments in renewable energy projects. Based on these actions, those interested in using or acquiring energy from renewable sources would have more options to choose from.

Table 1: Root causes and actions of economic/socioeconomic factors

UDE	Description	Action
50	There is a lack of incentive and financing policies	Have regulations for subsidies Have a level of support based on production Have a level of financial support Have investment-based support level
51	Uncertainty regarding financial return on investments	Have payment (bonus) for network benefits and remunerating smartgrids
57	There is uncertainty regarding the Operation and Maintenance costs (O&M)	There are options for small consumers to participate more actively in the process associated with electricity, considering the uncertainties of O&M costs
12	Maintenance cost is high	
84	There are long-term contracts (auctions) in place	Reallocate or redistribute from current contracts
82	Concessionaire are reducing their operations	Being an economically attractive model for the players that work in SEB
72	There is high investment in transmission and generation	Avoid the Averch-Johnson effect

There is also the "51. Uncertainty regarding financial return on investments" and based on this, the experts of the research instrument and focus groups suggested "Having payment (bonus) for network benefits and remunerating smartgrids," so that when consumers contribute to the energy network, are being benefited, as with the feed in tariff. In addition, remunerating those who contribute with energy efficiency gains from smart grids is a form of incentive for the energy transition, as every new technology needs subsidies to develop. Therefore, new options for small consumers to participate more actively in the process associated with electricity are necessary.

The root cause "57. There is uncertainty regarding the Operation and Maintenance costs (O&M)" is related to the different variables involved in the operation and maintenance of all types of power generation. Among the variables involved in O&M costs are the level of technology maturity, the quality of skilled labor, financing and interest rates, environmental factors, local problems, vulnerability in estimating man and machine resources, repair rate and replacement, planning failure, parts availability and monitoring supply (Kumar and Saini, 2022). Based on these issues, there needs to be more "options for small consumers to participate more actively in the process associated with electricity considering the uncertainties of O&M costs". This issue must be considered when formulating policies related to the SE, considering that this environment depends on complex operation and maintenance for monitoring, from energy generation to consumption and management by the consumer autonomously. The action in question also contemplates the root cause "12. Maintenance cost is high."

According to an expert in the focus group, the electricity companies would like the energy model not to change, and therefore, "83. Concessionaires prefer that consumers do not migrate to other forms of energy generation," due to the long contracts signed through auctions. According to an expert, it is through the concession contracts that who, how and for how much energy supply services will be provided are defined. Considering that these contracts are defined for a long period, which added to the fact that residential and commercial units are migrating to their own generation and, therefore, less need for supply by distributors, there is currently a surplus of energy (having given that it has already been contracted). In this sense, the root cause "84. There are long-term contracts (auctions) in place" has the action to "Reallocate or redistribute from current contracts" to current concession contracts, so that this issue is not harmful to concessionaires who would not need to go against the opening of the free market and the growth of distributed generation.

There is pressure from companies that do not want to lose their profits (UDE 58) because "81. Companies in the electricity sector

may have a drop in revenue" and because "82. Concessionaire are reducing their operations." In this sense, "considering that the SE will have the function of providing services to energy consumers and the SEB (Brazilian Electric System) is composed of all stages of the electrical chain, there will be resistance on the part of this group during the migration process to the SE" (expert respondent). Therefore, the action for the root cause 82 is "Being an economically attractive model for the players that work in SEB". Therefore, to replace the current service with a cloud-based energy management environment, policies that support the propagation of clean and distributed energy and that are interesting for both parties (utilities and consumers) are incentives for SE, since the business tends to develop if it is advantageous from an economic point of view.

As the SE evolves, the demand for infrastructure decreases, and with that, expenses with energy generation and transmission will be lower. As a result, infrastructure providers are at a disadvantage, as investments in generation and transmission would be lower, which is not well seen by this market. Thus, UDE 72 concerns the fact that there is high investment in transmission and generation, therefore, a focus group expert suggested, as an action for this root cause, the need for regulations that avoid the Averch-Johnson effect. This concept occurs when there is an incentive to over-invest and generates an inefficient allocation of resources, where investment in technologies provides a return higher than the cost of invested capital, and productive efficiency could be maintained without the investment (Siciliano, 2005). Therefore, for the evolution to the energy management environment in the cloud to occur, there is an impasse between not having to invest in infrastructure and the fact that this is not beneficial for large energy generation and transmission companies.

4.2. Personal or Sociocultural Factors

Considering personal or sociocultural issues, according to the CRT, 4 root causes were identified and 8 actions (Table 2) to assist in the development of a regulatory scenario for SE were suggested. These factors refer to the awareness of energy consumers with regard to new technologies and how policies can influence the dissemination of knowledge about this issue, in order to have greater acceptance.

Considering the complexity involving the technologies and information that SE involves, it is clear that only part of the population has access to these technologies (UDE 19), one of the reasons is the fact that "20. There are cultural and economic differences between regions." In order to map and regulate issues of access and dissemination of technologies, and for SE policies to be clear, they need to be widely disseminated through a national educational strategy to provide easy understanding to the population. In this bias, it is suggested to "Implement pilot projects" to spread the idea about SE and its benefits. According to an expert, "policies related to SE need to be clear and widely disseminated through a national educational strategy in a way that provides easy understanding to the population" (expert interviewed). Brazil, for example, is still far from a broad digital interconnection, a factor that, in addition to economic factors, is also due to the lack of knowledge about this issue. Thus, places that already have a greater diffusion of renewable energy can serve as pilot projects, with the objective of disseminating the SE concept and bringing the consumer closer to this model, in order to make it a reality.

Table 2: Root causes and actions of personal or sociocultural factors

UDE	Description	Action
20	There are cultural and economic differences between regions	Implement pilot projects
21	There is little involvement of the rural, industrial and commercial classes in policy-making	Implementing social work
22	The continental, social, cultural and economic dimensions are not considered	Have an intensive government/country program on explanation and awareness Disseminating information about new energy technologies Disseminating knowledge about Smart Energy Disseminate policies through a national educational strategy to provide easy understanding to the population Developing tools to accelerate the insertion of people in the world of modern energy
29	The technologies involved (such as IoT and Big Data) are expensive	Have government and private sector support

Following the same line, it is notorious that "21. There is little involvement of the rural, industrial and commercial classes in policy-making." These three classes could be participating more actively in the creation of policies for SE consolidation and thus contributing to the progress of this environment. According to an expert interviewed, in the very near future, the country will be strongly interconnected, and the biggest challenge will be the cultural and economic differences between regions, in a country of continental dimensions. Therefore, the "Implementing social work" aimed at the practice of actions aimed at the development and benefits of renewable energies, with the objective of improving social responsibility with the issue, is essential in the process of raising awareness of less participatory classes.

For the root cause "22. The continental, social, cultural and economic dimensions are not considered," five actions were suggested. Considering that consumers themselves will be able to manage their own energy, but many do not have the proper knowledge about the free energy market and are unaware of the existence of this possibility. Therefore, the focus group experts pointed out the need to "Have an intensive government/country program on explanation and awareness" to explain this issue to consumers, in order to explain as little as possible in mass. "The consumer does not need to know the details, but he needs to understand what he will have to manage, how to buy energy and how to negotiate this issue" (expert interviewed).

Experts corroborate the need to disseminate knowledge about SE, considering that "as a negative impact of the massive insertion of technology, one can cite the lack of democratization in this implementation, so technology must be accessible to all, without privileging those who have better financial conditions" (expert interviewed). Therefore, the dissemination of knowledge must be broad and with the help of market agents interested in the development of this scenario. Because if this is not a demand on the part of society, investments and development of public policies may be unfeasible. Thus, the actions "Disseminating information about new energy technologies" and "Disseminating knowledge about Smart Energy" are suggested in order to "gain collective awareness of the importance of energy efficiency, since consumers need to feel present and be part of this process" (expert interviewed), taking into account the demand and mapped need.

For SE policies to be clear, it is necessary to "Disseminate policies through a national educational strategy to provide easy understanding to the population". It is also suggested "Developing tools to accelerate the insertion of people in the world of modern energy," because according to the expert interviewed, "there is still a lack of universal access to energy in Brazil, and the development of these tools is of fundamental importance."

"26. The massive insertion of technology is not democratic" because the "27. Smart grids are accessible to those with greater financial conditions" because "28. The costs are high," likewise "29. The technologies involved (such as IoT and Big Data) are expensive." This root cause is in line with the others cited, as this issue makes it difficult for a large part of the population not to have access to the artifacts necessary for the functioning and monitoring of the SE. Therefore, "Have government and private sector support" is a suggestion. Policies that encourage both bodies to support the consumer could make the acquisition of technologies more inclusive and help insert people into the world of modern energy.

4.3. Availability Factors

The CRT of the availability factors identified 5 root causes (Table 3) that hinder the development of regulation for the SE, and 4 actions were pointed out. Availability factors are those referring to the access that consumers have to renewable technologies and energies.

The main availability factor that interferes in the creation of public policies is found in the lack of connection to the transmission and/or distribution network, which makes any consumption of renewable energies unfeasible, which in most cases are located in locations far from the load center. Because according to the expert interviewed, "the distribution system can influence the availability of energy." Brazil has the National Interconnected System which aims to resolve this availability factor. However, there are still regions that are not connected to the System. Thus, for root causes "6. Low level of population residing in rural areas" and "7. The consumption of renewable energy in remote areas from the load center is rendered unfeasible," it is essential to "Enable the consumption of renewable energy in locations far from the load center" and "Encourage the creation of policies for the development of the distribution sector," so that policies that develop the distribution link make it possible to increase efficiency and greater connection of energy systems.

Table 3: Root causes and actions of availability factors

UDE	Description	Action
6	Low level of population residing in rural areas	Enable the consumption of renewable energy in locations far from the load center
7	The consumption of renewable energy in remote areas from the load center is rendered unfeasible	Encourage the creation of policies for the development of the distribution sector
9	The digital communication networks for long-distance data transmission are inadequate	Expand the communication and network infrastructure
10	The internet is essential for the operation of the SE	
13	There is a lack of qualified personnel	Create TG for SE

Another point that delays the insertion of people in modern energy (UDE 2) and that makes the development of SE slow (UDE 14), is the fact that the internet is unavailable (UDE 8), because "9. The digital communication networks for long-distance data transmission are inadequate" and "10. The internet is essential for the operation of the SE." The communication networks are a fundamental point for the development of the SE, considering that one of the main layers of the SE is the Network layer, responsible for all the communication networks, and this data transmission occurs over a long distance, from the domains from users to where cloud data centers are located (Schaefer et al., 2020). Still, according to the expert interviewed, "the current communication and network infrastructure needs to be on an equal footing with advances." Therefore, for root causes 9 and 10, the action "Expand the communication and network infrastructure" is suggested, in order to contribute to the issue of availability of communication networks. For the root cause "13. There is a lack of qualified personnel" is suggested to "Create TG for SE". One expert interviewed comments that the creation of a TG (Technical Group), involving representatives and entities from the sectors that the SE comprises, would have the objective of raising technical requirements for proposing a regulatory framework aimed at this scenario.

4.4. Institutional and Market Factors

Four root causes and 4 actions related to institutional and market factors were identified (Table 4) to contribute to SE regulation. These factors are related to the benefits of energy conservation, professionals specialized in the subject, competition, currency risks and the energy market in general.

The root cause "104. The free energy market among all consumers is not yet regulated" is an UDE that entails a series of other effects, such as the fact that there is no market that supports the sale of direct energy between users (UDE 103), that consumers have little/no knowledge of the free market (UDE 102) and are not encouraged to be part of the energy decision-making process (UDE 101). Therefore, the regulation of a market that supports

the sale of direct energy between users is the action for this root cause. Regulation with this bias ensures safety between the energy exchange operation between consumers, which should be for everyone, such as generators and residential consumers, and not just those with high energy demand. This point would be a step forward on the way to an SE, since direct marketing between users is the key to this energy management model, and therefore, it is essential that consumers feel supported.

Since it is necessary to exchange experiences between countries, exchange rate risks must be considered in the process, as they interfere with the insertion of technologies for the consolidation of renewable energies and SE, If the "44. Currency risks negatively impact technological development," then "43. They interfere with the insertion of technologies for the consolidation of the SE," and because of that, "42. There is little interaction between countries to exchange experiences," in addition to a series of other EI that originate from the root cause 44. According to a experts, exchange rate risks negatively impact any technological development. At times when the national currency loses value, imported products become more expensive and impact the chain that depends on imports, which often has difficulty in transferring the value in contracts. Therefore, for root cause 44, it is suggested that regulators pay attention to formulating "policies for unpredictability related to currency risk", as these risks need to be identified, standardized and managed.

In light of the significant volume of data and information generated for managing this energy management scenario, there is a notable need for legal measures to regulate the utilization of data and cloud services. This data includes customer information and energy market details, such as prices, generation, and consumption. Furthermore, the security and privacy of this data must be carefully managed. Therefore, the proposed action, "Regulate other forms of energy flow: data and cloud usage," addresses the root cause 47 and recommends that policymakers prioritize this agenda.

Another aspect of institutional and market factors is the fact that the quality components offered in the SE are not standardized UDE 46). According to an expert, "reliability must be part of the first round of all due diligence", therefore, the action is to standardize these components to demand a minimum degree of compliance and guarantee a quality standard.

Table 4: Root causes and actions of institutional and market factors

UDE	Description	Action
104	The free energy market among all consumers is not yet regulated	Regulate a market that supports the sale of direct energy between users
44	Currency risks negatively impact any technological development	Have policies for unpredictability related to currency risk
47	Other forms of energy flow (data and cloud usage) are not regulated	Rule other forms of energy flow: data and use of the cloud
46	Quality components offered on SE are not standardized	Standardize quality components being offered in SE

4.5. Regulatory Infrastructure

Regulatory infrastructure factors include government involvement, identification of regulators, business lobbying, and legal certainty. The fact that regulations are late (UDE 92) relates to the range of regulatory infrastructure factors, with one UDE occurring due to the 8 root causes identified in the CRT and listed in Table 5.

"56. There is legal uncertainty" is a root cause that leads to a series of other undesirable effects, because according to the CRT, this effect makes it difficult to create credit lines (UDE 63), hinders the functioning of the market (UDE 62), makes it unfeasible to take of decisions (UDE 61), reduces the interest of national and foreign investors (UDE 60). In addition, legal uncertainty creates uncertainty (UDE 55), makes investment high risk (UDE 54), delays the propulsion of 4.0 technologies in the electricity sector (UDE 53), among other UDEs. Therefore, the action for this cause is "Having legal certainty among those involved" is an essential issue for the development of the SE and is what will guarantee the stability of this energy management model, considering the investment that the area needs.

Starting from the fact that "93. Regulatory processes do not keep pace with technologies," an interviewed expert comments that "Brazil is behind on this point and regulation should already be more advanced in matters such as the sale of micro generation energy, and better definition of network tariffs for micro and mini generation". Therefore, considering root causes 94 and 99, it is necessary to "Have a public process to collect subsidies for proposing a regulatory framework" needs attention, since this action would focus on identifying alternatives and subsidies to review and propose regulatory standards for the sector.

Table 5: Root causes and actions of regulatory infrastructure factors

EI	Descrição	Ação
56	There is legal uncertainty	Having legal certainty among those involved
94	The regulatory agency's performance regarding regulation and technology is slow	Have a public process to collect subsidies for proposing a regulatory framework
99	Grid tariffs for micro and minigeneration are poorly defined	
95	Regulation for connection between users is important to account for injection/consumption	Having another division of the electricity sector other than generation, transmission, distribution and commercialization
96	It is important to regulate the physical platform for measurement/connection between microgrids	Have specific regulations for the SE, making existing institutions responsible
97	There is no regulation for a virtual energy management platform	
108	There is the perception that the government will "lose" if it is not excessively regulated	Sharing SE responsibility between public and private
100	The monomial tariff is outdated	Possess a binomial tariff implementation calendar
		Have pilot projects by micro region to test the model

Root causes 95, 96 and 97 concern regulations related to the interconnection between users and energy management through digital platforms. Considering this connection between energy and data infrastructures to provide the most flexible and dynamic environment possible for users of energy systems, it is evident that for the SE context, the electricity sector cannot be divided only into generation, transmission, distribution and marketing. Therefore, this model needs specific regulation, which, in addition to infrastructure and market issues, guarantees legal certainty between injection, consumption, measurement and connection between microgrids, and transactions between a virtual energy management platform. Furthermore, responsibility for regulating a cloud-based energy scenario must converge with the regulatory body and established entities. Because instead of creating more institutions, existing ones should be strengthened to enforce the SE concept. One expert reinforces that regulatory bodies could improve their performance in terms of keeping up with the challenges of implementing technologies involving decentralized energy.

Another factor of debate is whether energy is regulated by private or government agencies. The root cause "108. There is the perception that the government will "lose" if it is not excessively regulated" is related to this issue. Some experts argue that energy cannot be regulated by an autonomous agency that defends interests and that it is a fundamental matter of a government. However, according to the CRT, this issue has the disadvantage of the delay in the process, considering that the "107. Government overregulates" and "106. Decision making is slow" and also "105. The regulatory process is slow." Government policies may speed up or slow down the process, and it may not continue due to elections. The fact that the energy regulation process is carried out by the private sector would have the risk of self-benefit.

In this sense, another experts reinforces that the regulation process should be the role of the State, which needs to ensure the balance of relations between investors and energy users. Therefore, policies need to be formulated independently of the government administration, and according to an expert interviewed, the responsibility for the SE needs to be shared, but led by the National Congress and by a regulatory agency that acts independently of changes in government. Therefore, one should "Share the responsibility of SE between public and private." Thus, regulation must be independent, without public and private interests, but with supervision by public entities.

Another issue is the root cause 100 about the fact that the monomial tariff is out of date. A experts from the focus group comments on the migration from the monomial tariff to the binomial tariff, commenting that "a priori, changing the tariff structure, considering the current generation model, which is still very dependent on centralized generation and intensive use of the network, will increase the tariff at first, because the investment in technology and investment to make the binomial tariff viable would be large. The binomial tariff will only become cheaper when there is an offer of distributed generators with cheaper energy and the possibility of exchanging energy between users. So, there is an initial decoupling (investment and impact of the new tariff) to increase the reserve for distributed generation and equipment to make the smart grids work, thus having a great impact on the initial investment, but which in the long term tends to lower the tariff". Thus, in the short term it becomes more expensive, but in the future it makes the rate cheaper. Therefore, a change to a binomial tariff system through an implementation calendar is suggested, as this change should happen gradually.

Still, experts suggest the need to "Have pilot projects by micro regions to test the model," considering that technology is always ahead of legislation, so these projects would serve as a first experience and would be able to show that networks can work in a similar way. isolated way, and from that, with technologies such as storage, it is possible to clarify the SE concept. As this concept is not going to expand quickly nationally, it is suggested to work by micro-region so that later on it will have conditions for consolidated regulation.

4.6. External and Information Factors

External and information factors refer to energy consumption data, support information, policies that are not related to energy, and companies that influence the decisions of regulatory agencies. According to CRT and Table 6, there are 6 root causes linked to these factors.

The fact that the consumer is unaware of generation and consumption data (UDE 25) is something that leads to a series of other effects, because if this exists, then there is a lack of knowledge about these data (UDE 24), there are doubts about how management is carried out (UDE 23), and therefore most

Table 6: Root causes and actions of external and information factors

UDE	Description	Action
25	The consumer is unaware of generation and consumption data	Represent data and have stakeholder transparency Using public hearings and consultations as inputs
36	There is a lack of research and development (R&D) projects in the energy sector	Have more participation from research institutions
37	At times, energy company managers disregard the benefits of other sources of electricity generation	
40	There is a lack of specific regulation regarding disposal/recycling	Have specific regulation
78	It is not only energy-focused regulations that interfere with the development of the SE	Have an infrastructure system Increase communication networks for long-distance data transmission Exist data security and privacy Existing broker for buying and selling Regulate data processing and storage Regulate platform services
80	Judicial issue hinders the role of the regulator	Have more position from the regulatory body

consumers are not interested in these issues (UDE 18), in addition to jeopardizing the maximization of results by increasing risks, generating unnecessary costs and impairing energy efficiency. So, "Representing the data and having transparency of the interested parties" and "Using public hearings and consultations as inputs" are suggested, with the objective of gathering subsidies and information from society, which would be collaborating with the energy sector and with the democratization of the sector. According to an expert, the information on consumption and production needs to be known by the regulatory agency so that strategies for the economic sustainability of energy as a whole are established. Therefore, consumer awareness of the issue of information collection, through organized social movements, for example, is an alternative for communication between consumers and those responsible for regulation, since in a transition phase to an innovative environment, all information is required and important.

Root causes 36 and 37 lead to other unwanted effects such as lack of understanding regarding the contribution of new technologies to energy management (UDE 35) and insufficient training regarding the adoption of new energy technologies (UDE 34). The delivery of products and services through Research and Development Projects contribute to technological progress and understanding of the benefits of technologies involved in energy generation and SE management, in addition to strengthening the know-how on the part of policy makers who would access to information generated through these projects. Therefore, the action "Having more participation from research institutions" for root causes 36 and 37 is important, bearing in mind that SE is still an expanding phenomenon that needs more study, more research and more development. In this sense, stakeholders and auditing organizations need to be answered, so that operations can be audited and monitored, with the aim of ascertaining consumption, energy efficiency of equipment, losses, and whether SE management is being carried out. Effectively, which reinforces the need to demonstrate data on energy consumption and production. As the SE encompasses a mix of energy generation from renewable sources, another challenge is the regulations related to the disposal or recycling of the materials involved in this process. Therefore, considering all the benefits of solar energy, there is an urgent need to pay attention to the root cause "40. There is a lack of specific regulation on disposal/recycling," which requires legal decommissioning measures.

It is known that SE is made up of different layers, each one responsible for its specific function or service, and therefore, "78. It is not only energy-focused regulations that interfere with the development of the SE". This root cause carries over to other EIs, such as the fact that "76. External factors beyond regulations interfere with the regulatory process of the SE" which then depends on policies coming from other sectors (UDE 75), and not just policies focused on energy (UDE 74). Therefore, for the regulation of this system, some points must be considered, such as "Have an infrastructure system", which refers to all infrastructure responsible for energy services and services related to data management and storage, and "Increase communication networks for long-distance data transmission" are factors external to energy regulation that need attention when considering a regulatory arrangement for the SE. Regulations focused on data security and privacy is another necessity, considering that the SE is an interconnected system that needs a high level of security and integrated privacy between all layers (Carvalho et al., 2021). There is a need for rules to conduct the brokerage services for purchase and sale, given the autonomy that consumers will have for managing the purchase, exchange and sale of energy, and cloud services. There is also a need for regulatory actions aimed at data processing and storage, such as regulations focusing on the energy efficiency of data centers and the efficient allocation of tasks to be performed in the cloud (Carvalho et al., 2021). Still, regulators should pay attention to rules that guide platform services, which will intermediate interactions between consumers (de Carvalho et al., 2022).

Another point is the interference of the judiciary sector in regulations, which hinders the role of the regulatory agent (UDE 80). Political interference is an external factor that interferes with regulatory decisions, since, according to a experts in the focus group, decisions need to be taken with greater technical quality and be guided by the regulatory framework and not by political contexts. This happens with some bills that, for political reasons, are not approved. Therefore, it is necessary to "Have more positioning from the regulatory body," which must be positioned against these issues so that interference decreases. These UDE refer to policies in other sectors and are not directly related to energy, but are key sectors for the operation of the SE and must be considered when establishing a set of regulatory measures.

4.7. Ideology Embedded in Regulation

The ideology factors embedded in regulation refer to issues of ideology of regulatory agents, interest group rivalry, and country pluralism. Four root causes and 2 actions were identified for these factors (Table 7).

The root cause "71. There are ideological factors embedded in the regulation" added to the root cause "73. The plurality of interests makes it difficult to create and propagate SE-oriented policies", entails a series of other UDEs, such as the fact that there is pressure from associations and groups of companies such as integrators and distributors (UDE 70), who want the government to adapt based on your preferred solution (UDE 69). Along these same lines, the root cause "89. Rivalry between interest groups affects

Table 7: Root causes and actions of ideology embedded in regulation

UDE	Description	Action
71	There are ideological factors embedded in regulation	Hold the regulatory body accountable for balancing the forces of diversity of opinion
73	The plurality of interests hinders the creation and propagation of policies focused on the SE	
89	Rivalry between interest groups affects the distribution of subsidies	
67	Companies want policies according to their own technologies	Give autonomy to the regulatory body

the distribution of subsidies" leads to consumers not being able to quickly benefit from new technologies (UDE 88), slows down the development of new markets (UDE 87), and other UDEs. The action "Make the regulatory body responsible for balancing the forces of diversity of opinion" is suggested for root causes 71, 73 and 89, as regulatory agencies have the mission of balancing the interests of business groups with those of society. Rivalry between interest groups must be treated with caution and in such a way as not to affect the development of new electricity markets such as the SE, nor hinder consumers' access to new technologies.

From the root cause "67. Companies want policies according to their own technologies" other UDEs are pointed out, such as the fact that "66. Industry giants can align forces for technology offerings" and then there are questions related to lobbying by these companies with policy makers and governments (UDE 65). Therefore, experts reinforce that it is necessary to strengthen the energy regulatory body to deal with lobbying issues. Considering this need, the action for this root cause is "Give autonomy to the regulatory body" so as not to benefit only one sector of the energy market in particular.

5. CONCLUSIONS

Energy regulation is a process that involves several actors, stages and factors that interfere in decision-making, in the development and propagation of a more digitized and dynamic energy scenario, mainly composed of renewable energies. In view of this, knowing and analyzing the functioning of this system and identifying what are the problems that delay or limit the progress towards innovation, is an important issue for the future of the energy sector. Therefore, the objective of this article was to propose a diagnosis with propositions of guiding actions for the current energy regulatory scenario directed towards Smart Energy.

Factors that interfere with energy regulation with an emphasis on SE, raised in the literature, were presented to experts in the energy sector through interviews, and with the collected information, an CRT was built. The insights presented in the CRT help to provide the proper direction for a regulation focused on a decentralized, democratic and dynamic energy scenario, as is the case of SE. This study has some practical implications for researchers, companies and energy regulatory bodies, among which some are highlighted below:

- It is necessary to raise consumer awareness through social policies and formulate strategies to implement these policies, in order to address environmental issues and lack of knowledge about smart technologies for energy generation and management. Consumers must be actively involved in smart grid technologies.
- Technologies must be accessible to all, and policies aimed at providing access subsidies for the acquisition of technologies for implementation and monitoring are necessary, so that consumers begin to be more active throughout the electricity process. Because, without publicizing and training society on new technologies and forms of relationship with energy companies, there may be resistance to changes, as they may not see the benefits.
- The SE will develop if it is advantageous from an economic point of view and that is why it is important to prioritize the interests of the players, although there may be resistance from them due to the changes that the SE brings with it. As an example, there is the current concession model (contractual), which can make the formation of this new model difficult.
- Responsibility for SE regulation needs to be shared between public and private. As it is public, it has the advantages of being a neutral element in the process and favoring the public interest, in addition to ensuring transparency and being able to be charged, however, as a disadvantage, it is possible to mention the slowness in the process and decision-making. An autonomous agency could defend the interests of some players or benefit itself. Therefore, regulation and inspection must be public.

This study was limited to making a diagnosis of the current energy regulation scenario, and through this, the deficiencies were analyzed and what can be changed to have a cloud-based energy management. Therefore, in this study, energy regulations were not analyzed and new laws were not suggested, but guiding paths were presented to regulate and enable the regulatory environment to support the insertion of technologies related to the theme. Still, this study has academic relevance (in view of the growing publications on the subject) and organizational relevance. What proves its importance at an organizational level were the interviews and focus groups with experts in the area, who were interested and committed to the theme. In this way, this study and the results raised in it provide a guide for policy formulation and goal setting, being useful for researchers, policy makers governments and other interested institutions. Government policies that are practical and beneficial must be developed to help build consumer confidence in a cloud-based energy management model. As future research, it is suggested the elaboration of a framework that contemplates who are the players responsible for each of the actions suggested in this research.

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REFERENCES

Adly, B., El-Khouly, T. (2022), Combining retrofitting techniques, renewable energy resources and regulations for residential buildings to achieve energy efficiency in gated communities. Ain Shams Engineering Journal, 13(6), 101772.

Aikenhead, G., Farahbakhsh, K., Halbe, J., Adamowski, J. (2015), Application of process mapping and causal loop diagramming to enhance engagement in pollution prevention in small to medium size enterprises: Case study of a dairy processing facility. Journal of Cleaner Production, 102, 275-284.

Al Faruque, M.A., Vatanparvar, K. (2016), Energy management-as-a-service over fog computing platform. IEEE Internet of Things Journal, 3(2), 161-169.

Alnowibet, K., Annuk, A., Dampage, U., Mohamed, M.A. (2021), Effective energy management via false data detection scheme for the interconnected smart energy Hub-microgrid system under stochastic framework. Sustainability, 13(21), 11836.

Archana, S.R., Singh, S. (2022), Development of smart grid for the power sector in India. Cleaner Energy Systems, 2, 100011.

Armstrong, J.H. (2019), Modeling effective local government climate policies that exceed state targets. Energy Policy, 132, 15-26.

Ben Abdeljawed, H., EI Amraoui, L. (2021), Prospects for synergies between low-voltage DC microgrid technology and peer-to-peer energy trading markets. Sustainable Production and Consumption, 28, 1286-1296.

Bento, N., Borello, M., Gianfrate, G. (2020), Market-pull policies to promote renewable energy: A quantitative assessment of tendering implementation. Journal of Cleaner Production, 248, 119209

Bhanot, J., Jha, V. (2012), Moving towards tangible decision-making tools for policy makers: Measuring and monitoring energy access provision. Energy Policy, 47(Suppl.1), 64-70.

Carvalho, P.S., Siluk, J.C.M., Schaefer, J.L., Pinheiro, J.R., Schneider, P.S. (2021), Proposal for a new layer for energy cloud management: The regulatory layer. International Journal of Energy Research, 45, 9780-9799.

Da Costa, J.M.H., Amaral, C.S.T., Fernandes, S. Da C., Rozenfeld, H. (2018), A new way to diagnose the new product development process based on recurring current reality trees. Business Process Management Journal, 25(4), 667-687.

De Carvalho, P.S., Siluk, J.C.M., Schaefer, J.L. (2022), Mapping of regulatory actors and processes related to cloud-based energy management environments using the Apriori algorithm. Sustainable Cities and Society, 80, 103762.

Esapour, K., Moazzen, F., Karimi, M., Dabbaghjamanesh, M., Kavousi□Fard, A. (2022), A novel energy management framework incorporating multi□carrier energy hub for smart city. IET Generation, Transmission and Distribution. 17, 655-666.

Fang, D., Guan, X., Lin, L., Peng, Y., Sun, D., Hassan, M.M. (2020), Edge intelligence based economic dispatch for virtual power plant in 5G internet of energy. Computer Communications, 151, 42-50.

Frate, C.A., Brannstrom, C. (2017), Stakeholder subjectivities regarding barriers and drivers to the introduction of utility-scale solar photovoltaic power in Brazil. Energy Policy, 111, 346-352.

Giordano, A., Mastroianni, C., Sorrentino, N., Menniti, D., Pinnarelli, A. (2019), An energy community implementation: The unical energy cloud. Electronics (Switzerland), 8(12), 8121517.

González, M.O.A., Gonçalves, J.S., Vasconcelos, R.M. (2017), Sustainable development: Case study in the implementation of renewable energy in Brazil. Journal of Cleaner Production, 142, 461-475.

Iwaro, J., Mwasha, A. (2010), A review of building energy regulation and policy for energy conservation in developing countries. Energy Policy, 38(12), 7744-7755.

Jackson Inderberg, T.H., Sæle, H., Westskog, H., Winther, T. (2020), The dynamics of solar prosuming: Exploring interconnections between actor groups in Norway. Energy Research and Social Science, 70, 101816.

Jararweh, Y. (2020), Enabling efficient and secure energy cloud using edge computing and 5G. Journal of Parallel and Distributed Computing, 145, 42-49.

Kim, J.Y., Cho, S.B. (2021), Explainable prediction of electric energy demand using a deep autoencoder with interpretable latent space. Expert Systems with Applications, 186, 115842.

Kristensen, H.S., Mosgaard, M.A., Remmen, A. (2021), Integrating circular principles in environmental management systems. Journal of Cleaner Production, 286, 125485.

Kulkarni, N., Lalitha, S.V.N.L., Deokar, S.A. (2019), Real time control and monitoring of grid power systems using cloud computing. International Journal of Electrical and Computer Engineering, 9(2), 941-949.

Kumar, K., Saini, R.P. (2022), Economic analysis of operation and maintenance costs of hydropower plants. Sustainable Energy Technologies and Assessments, 53, 102704.

Lacerda, D.P., Cassel, R.A., Rodrigues, L.H. (2010), Service process analysis using process engineering and the theory of constraints thinking process. Business Process Management Journal, 16(2), 264-281.

Liu, Y., Yang, C., Jiang, L., Xie, S., Zhang, Y. (2019), Intelligent edge computing for IoT-based energy management in smart cities. IEEE Network, 33(2), 111-117.

Lowalekar, H., Ravi, R.R. (2017), Revolutionizing blood bank inventory management using the TOC thinking process: An Indian case study. International Journal of Production Economics, 186, 89-122.

Morelli, G., Magazzino, C., Gurrieri, A.R., Pozzi, C., Mele, M. (2022), Designing smart energy systems in an industry 4.0 paradigm towards sustainable environment. Sustainability, 14(6), 3315.

Noreen, E.W., Smith, D., Mackey, J.T., IMA Foundation for Applied Research, and Price Waterhouse (Firm : France). (1995), The Theory of Constraints and its Implications for Management Accounting. United States: North River Press. p187.

Okwanya, I., Alhassan, A., Migap, J.P., Adeka Sunday, S. (2020), Evaluating renewable energy choices among rural communities in Nigeria. An insight for energy policy. International Journal of Energy Sector Management, 15(1), 157-172.

Parvin, K., Hannan, M.A., Hui Mun, L., Hossain Lipu, M.S., Abdolrasol, M.G.M., Jern Ker, P., Muttaqi, K.M., Dong, Z.Y. (2022), The future energy internet for utility energy service and demand-side management in smart grid: Current practices, challenges and future directions. Sustainable Energy Technologies and Assessments, 53, 102648.

Pereira Bastos, S.A., De Macedo-Soares, T.D.L.A. (2011), Framework for the analysis of corporate political strategies pertinent to regulation: A relational perspective. Corporate Ownership and Control, 8(4 F), 487-498.

Quan, S., Wang, Y.X., Xiao, X., He, H., Sun, F. (2021), Real-time energy management for fuel cell electric vehicle using speed prediction-based model predictive control considering performance degradation. Applied Energy, 304, 117845.

Rahman, S.U. (2002), The theory of constraints' thinking process approach to developing Growth strategies in supply chain. International Journal of Physical Distribution Logistics Management, 32(10), 809-828.

Renugadevi, N., Saravanan, S., Naga Sudha, C.M. (2021), IoT based smart energy grid for sustainable cites. Materials Today: Proceedings. 81, 98-104.

Saidani Neffati, O., Sengan, S., Thangavelu, K.D., Dilip Kumar, S., Setiawan, R., Elangovan, M., Mani, D., Velayutham, P. (2021),

Migrating from traditional grid to smart grid in smart cities promoted in developing country. Sustainable Energy Technologies and Assessments, 45, 101125.

Schaefer, J.L., Siluk, J.C.M., Carvalho, P.S. (2021), An MCDM-based approach to evaluate the performance objectives for strategic management and development of energy cloud. Journal of Cleaner Production, 320, 128853.

Schaefer, J.L., Siluk, J.C.M., Carvalho, P.S., Renes Pinheiro, J., Schneider, P.S. (2020), Management challenges and opportunities for energy cloud development and diffusion. Energies, 13(16), 4048.

Siciliano, A. (2005), Regulação incentivada: Simplificação ou complicação na supervisão das concessionárias de eletricidade? Revista Do BNDES, 12(3), 243-266.

Song, M., Meng, J., Lin, G., Cai, Y., Gao, C., Chen, T., Xu, H. (2022), Applications of shared economy in smart grids: Shared energy storage and transactive energy. The Electricity Journal, 35(5), 107128.

Stefan De Carvalho, P., Cezar, J., Siluk, M., Schaefer, J.L. (2022), Analysis of factors that interfere with the regulatory energy process with emphasis on the energy cloud. International Journal of Energy Economics and Policy, 12(2), 325-335.

Tiwari, K., Khan, M.S. (2020), Sustainability accounting and reporting in the industry 4.0. Journal of Cleaner Production, 258, 120783.

Tronchin, L., Manfren, M., Nastasi, B. (2018), Energy efficiency, demand side management and energy storage technologies-a critical analysis of possible paths of integration in the built environment. Renewable and Sustainable Energy Reviews, 95, 341-353.

Zamani, R., Parsa Moghaddam, M., Haghifam, M.R. (2022), Evaluating the impact of connectivity on transactive energy in smart grid. IEEE Transactions on Smart Grid, 13(3), 2491-2494.

Zhang, Q., Bai, F., Yu, Z., Liu, Y., Shen, T., Xie, A., Huang, L. (2022), Editable and verifiable anonymous authentication incorporating blockchain in the internet of energy. Electronics, 11(13), 1992.

APPENDIX A-RESEARCH INSTRUMENT I-SCRIPT OF INTERVIEWS FOR CRT

Diagnosis of the Energy Regulatory Scenario with Emphasis on Smart Energy

Smart Energy is a multidirectional network that will offer the interconnection of end users, favoring the generation, storage, consumption and sharing of electrical energy. This energy management model will occur through online platforms, which will be managed by network orchestrators that connect customers to services.

As it is a future model, Smart Energy still does not have a body responsible for inspection, regulation and control. Therefore, the general objective of this research is to propose a diagnosis for the Smart Energy regulatory scenario.

The purpose of this data collection instrument is to collect information about your perception of the energy regulation process with an emphasis on the Smart Energy scenario.

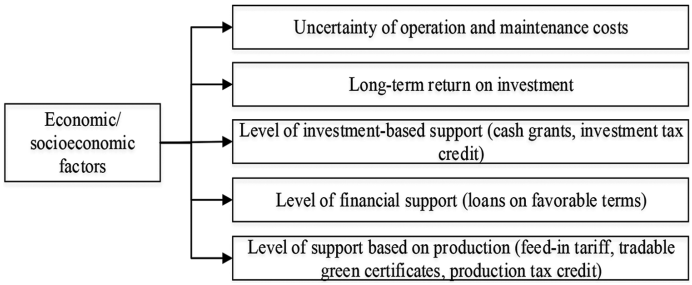
Therefore, you, indicated as an expert and representative of the area, will answer this scientific research instrument according to the script below. The interview script is distributed according to factors that interfere in the energy sector regulation process and is composed of discursive questions.

Term of Consent: by consenting, you declare that you authorize your participation and that your collected data will be used as part of a scientific research work.	YES	NOT

Characterization of respondents	
Which alternative best defines your performance in the field of energy management?	**Check the corresponding option**
Government representative	
Member of regulatory agency or association of energy companies	
University researcher or professor	
Representative of public, private financial agents or investor in the energy area	
Representative of a company that is part of the supply chain related to the energy sector and data cloud (manufacturers, developers, installers, etc.)	
Power systems user	
Representative of a service provider in the area of energy and data cloud (data centers, utilities, generation, transmission or distribution companies)	
Which of the options below best describes your role in your organization?	**Check the corresponding option**
Owner or shareholder	
director or manager	
Position in the technical area (Technician/ Supervisor/Analyst)	
Researcher or consultant	
Self-employed	
Other	

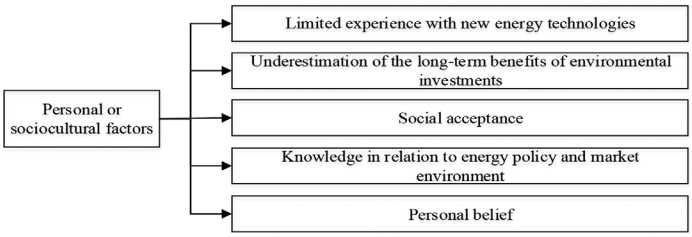
In which country do you reside?

Economic/socioeconomic factors



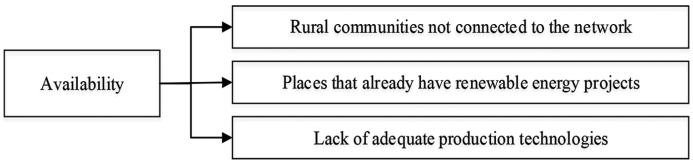
1. How do you think economic factors are influencing the development of policies that favor the consolidation of Smart Energy?
2. Do you consider that there is a lack of financial support from the government and subsidy policies in relation to investments for self-generation of energy? Why?
3. Do you agree that feed-in tariffs, negotiable green certificates or production tax credits are a viable option for financial incentives for the use of renewable energies? Why?
4. In addition to the above factors, do you have suggestions for economic factors that affect the creation of Smart Energy development and adoption policies? Which are they?

Personal or Sociocultural Factors



5. Why will experience and limited contact with new energy technologies affect the development of policies related to Smart Energy?
6. What are the causes for underestimating the benefits of implementing and using renewable energies? What negative impacts does this have?
7. What are the negative impacts of the massive insertion of technology for effective consumption of electricity? How can the policy development process contribute to changing consumer behavior to accept this coming digital interconnection?
8. In addition to the above factors, do you have suggestions for personal or socio-cultural factors that affect the creation of Smart Energy development and adoption policies? Which are they?

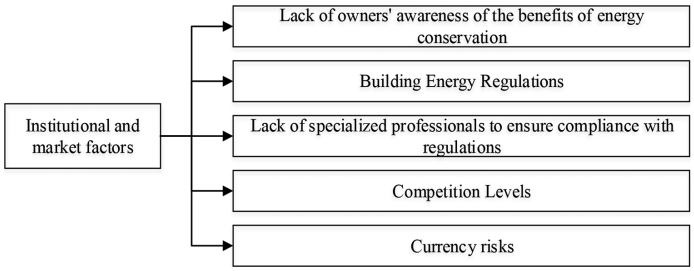
Availability Fator



9. How do you consider that availability factors (factors above) interfere in the creation of policies that contribute to the consolidation of renewable energies and Smart Energy?

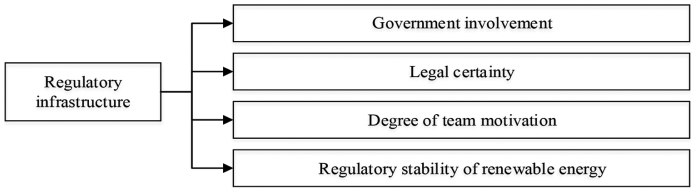
10. In addition to the above factors, do you have suggestions for availability factors that affect the creation of Smart Energy development and adoption policies? Which are they?

Institutional and Market Factors



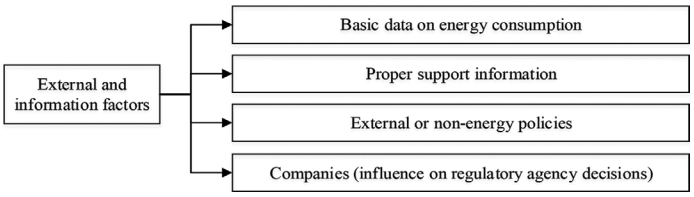
11. What changes should occur in the regulatory scope to support the entry of Smart Energy in the energy market?
12. Do you believe that there is insufficient training for managers in general (electricity companies) in relation to the entry of new energy technologies (generation, consumption, sharing and data management) in the market? As?
13. Do you believe that levels of competition and currency risks interfere in the development of policies that contribute to the consolidation of renewable energies and Smart Energy? As?
14. In addition to the factors presented above, do you have any suggestions for institutional and market factors that affect the creation of policies for the development and adoption of Smart Energy? Which are they?

Regulatory Infrastructure



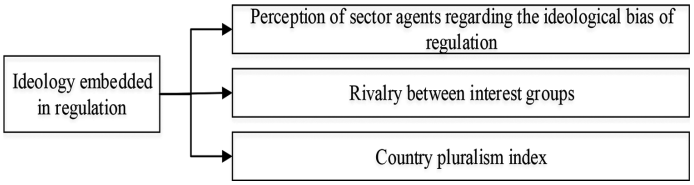
15. Is the change taking place in energy regulations keeping pace with the challenges of deploying technologies involving decentralized energy?
16. What negative impacts does the lack of legal certainty bring to the energy regulation process?
17. What are the advantages and disadvantages of government involvement in the energy regulation process? Do you consider it more advantageous for this responsibility to be public or private?
18. In addition to the above factors, do you have suggestions for factors related to the regulatory infrastructure that affect the creation of policies for the development and adoption of Smart Energy? Which are they?

External and Information Factors



19. Do you consider that external regulatory factors such as those in the figure above interfere in the energy regulatory process? As?
20. In addition to the above factors, do you have **suggestions** for factors related to external factors and information that affect the creation of policies for the development and adoption of Smart Energy? Which are they?

Ideology Embedded in Regulation



21. Do you consider that ideological factors such as rivalry between interest groups affect the development of energy regulatory policies? As?
22. Does a pluralized country make it difficult to create policies that favor the propagation of policies aimed at Smart Energy? As?
23. In addition to the factors presented above, do you have any suggestions for factors related to the ideology embedded in the regulation that affect the creation of policies for the development and adoption of Smart Energy? Which are they?