Analysis Of Challenges For Implementing Energy Storage In Distribution Systems To Support Climate Change Efforts

Renán Orellana-Lafuente, Ramiro Rojas-Zurita
Universidad Privada Boliviana
CESU, Universidad Mayor de San Simón
Cochabamba – Bolivia
renanorellana@upb.edu, ra.rojas@umss.edu

Miguel Edgar Morales Udaeta, Viviane Tavares Nascimento, André Luiz Veiga Gimenes
GEPEA - Energy Group, Escola Politecnica, Universidade de São Paulo,
São Paulo – Brasil
udaeta@pea.usp.br. viviane.tavares@usp.br, gimenes@gmail.com

***Abstract*— The purpose of this work is to present a comprehensive roadmap for the implementation of energy storage systems in emerging economies. In light of the global efforts to combat climate change, there is a need for a transition towards clean energy sources. However, the widespread availability of technologies and services that reduce carbon emissions is not uniform across the world. Economic and social inequalities pose significant barriers to the development of emerging economies, hindering their ability to meet environmental goals and achieve economic growth. To address this issue, the proposed work focuses on mapping the current state of renewables and energy storage systems in emerging economies. The information is classified into opportunities and uncertainties that may impact the implementation of storage systems. Furthermore, the strengths and weaknesses of the strategic positioning of emerging countries are analyzed in relation to the storage deployment. The barriers and opportunities are organized into a descriptive and actionable map that outlines the evolutionary process over time. The study also includes a use case for Brazil, evaluating the economic viability of energy storage as an alternative to diesel generators during periods of high energy demand. This analysis provides an overview of the current economic and social situation in the country and helps determine the potential for storage deployment. Finally, this work aims to provide a comprehensive scheme for the implementation of energy storage in emerging economies, addressing the economic and social barriers to the deployment of clean energy sources.**

Keywords—Energy Storage Systems; Emerging Economies; Distributed Generation; Roadmap

I. Introduction

The energy sector faces challenges in mitigating the effects of climate change, such as reducing its carbon footprint and expanding access to modern energy services. Despite this, the sector still heavily relies on fossil fuels to meet demand. In the 1990s, the total energy supply growth was 1.8% with renewable sources growing by 2% annually over the same period. The growth of renewable energy sources is largely driven by solar photovoltaic and wind power, which are increasing at an average rate of 36.5% and 23% per year respectively [1].

Battery Energy Storage Systems (BESS) are seen as a solution to accelerate the transition away from fossil fuels, mitigating the risks associated with intermittency and balancing supply and demand. However, there are challenges to overcome such as business continuity and market rule gaps, which are especially significant for emerging economies.

Emerging economies are expected to increase access to renewable energy sources, improve social inclusion and reduce inequalities. However, their current economic status creates barriers to access technology and investment, hindering their development. To overcome these challenges, market dynamics focused on reducing risks and facilitating new stakeholder involvement are needed.

To assist stakeholders, this work presents a roadmap for deploying BESS in emerging economies, mapping risks and opportunities for installation and outlining a path for increased adoption of the technology. The roadmap is based on data such as economic parameters, population and demand growth, regulations, supply chain and industry status, which are used to establish relevant steps for installation. The information is classified into risks and opportunities, guiding the definition of manageable steps over time. The roadmap also addresses new market structures and is expected to inform new business plans and energy policies for these countries.

The work is structured as follows: Section 2 reviews previous works on technology implementation and management, Section 3 outlines the analyzed scenarios, parameters and methods for assigning issues, Section 4 details the proposed tools and categories established by the method, and Section 5 concludes the work and outlines future research. The work also includes a use case focused on Brazil, which aims to define market rules for BESS implementation in the country, rather than facilitating the entry of the technology itself. electronic requirements that facilitate the concurrent or later production of electronic products, and (3) conformity of style throughout a conference proceedings. Margins, column widths, line spacing, and type styles are built-in; examples of the type styles are provided throughout this document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

II. CUTTING-EDGE RESEARCH

Current economic norms establish that renewable energy sources deployment depends on purchasing power. The usage of renewable sources is a reality for developed economies, allowing economic development and access to technologies. In contrast, developing economies do not have easy access to modern energy services and are not able to develop technology on their own. These facts highlight the unfair practices about economic and social development measurement through growing demand and consumption values. The inequality disturbs the technologies' installment, a precedent step for energy transitioning for all countries [2]. Economic affordability is a barrier for these countries, which leads to significant market risks and gaps. Stakeholders must be able to map the risks to make decisions on the technology implementation.

BESS is an important technology for the current transition scenario. Electrochemical batteries can convert electrical into chemical energy and reconvert to electrical energy, setting charge and discharge cycles [3], [4]. Yet, the implementation of a BESS solution is not a linear process: its entry as a large-scale solution requires the analysis of economic factors, the grid structure and resiliency, regulation, market factors, and framework, the energy usage profile, and consumers' expectations [5],[6].

The technology implementation for the energy sector demands a large analysis of data, requiring a management tool with a broad overview. A roadmap is a management tool developed according to project-specific goals that enable to map barriers and opportunities of a project deployment through a lifecycle [7],[8]. The roadmap sets the flow of processes, but adjustments during the project are expected, leading to a new time and steps definition [9]. The adaptability allows the learning during the project development, adjusting the steps according to the technology evolution, market movements, and recognized gaps.

Roadmaps on energy transition must cope with social and economic parameters, describing the relation of transition scenarios and socio-economic results [10]. This map must contain benefits and gaps for a region or country, establishing dynamics between the technological progress and the existing social and economic dynamics that promote scalability [10]. Climate and sustainability targets are mapped as well: environmental agreements and social pressure are relevant actions for stakeholders and government.

The emergent economies' path relies on international interests and local energy sector information. Cantarero [2] names instabilities in the energy sector, due to reforms and financial inconstancy, which may lead to divergent interests and high reliability in fossil fuels because of developed countries' influence. These factors address renewable implementation for developing economies and point out the influence of foreign actions in these countries. The author establishes that these parameters influence public policies on cleaner energy sources entry, establishing how regulation and subsidies are defined, and how the local energy sector deals with technologies deployment.

A technology deployment relies on governmental actions and energy policies instead of technological development. Policies establish conditions for price variation and subsidies that encourage new stakeholders as generators. These aspects lead to renewables growth in the country [2]. The encompassing information for renewables integration in Pakistan [11] points out the status of the local energy sector and the access to new sources as a result of governmental actions. Sadiqa et al. [11] sets that the country may take advantage of available primary sources but establishes that the energy storage systems deployment is a unique opportunity to enhance the renewable energy sources integration. The work cites the excessive costs of deploying a sustainable energy system as a barrier, requiring government actions and appropriate energy planning to overcome it. As a result, Cantarero [2] and Sadiqa et al. [11] establish that the costs and the affordability of the projects require stakeholders' attention, showing the importance of economic viability studies and energy planning for BESS.

Economic viability studies consider the energy demands, the technology status, and the integration with other renewable sources to reduce costs. Costs reduction is one aspect envisaged by stakeholders. The deployment of photovoltaic infrastructure and BESS may reduce the costs regardless of the natural degradation and aspects that hinder the system reliability [12]. The dispatch of the energy and the intensive deployment of the energy sources are parameters that reduce costs. The viability study addresses these aspects to enhance the initial investment: in conclusion, the inflated costs of buying and maintaining a BESS are a barrier for smaller consumers. Despite the intensive usage of photovoltaic panels, BESS is not an affordable system for smaller consumers.

The same conclusions exist for consumers located in the United States. Despite the advantage of a less costly energy source as an approach to ensure the affordability of BESS, the excessive costs are a barrier to consumers with smaller demands, such as residential consumers. The costs reduction through energy sources combination, the initial costs hinder technology, despite the price's variation for the grid. The excessive costs of energy services from the grid set conditions that increase advantages for consumers to reduce costs through self-supply [13]. Although the energy market changes from state to state, the combination of the sources set conditions for a grid replacement, but more affordable conditions to buy the system must be encouraged to allow viability for smaller consumers [13].

Barzegkar-Ntvom et al. [14] studies the viability to combine photovoltaic systems and BESS as an alternative to attend residential and commercial consumers. The authors focus on the viability of the mix of the sources to ensure the self-supply, enabling the balance of initial investment and the costs reduction through time. The variability of energy profile allows studying the impact of costs for distinct groups. Martine - Bolaños et al. [15] studies the viability of a combined BESS and Diesel Generator Set as a replacement to the grid. The Diesel Generator is a regular replacement for the grid in Brazil. Both works do not consider a profitable condition for hybrid systems but ensure modern technology access through the life cycle based on costs variation.

Barzegkar-Ntvom et al. [14] establish that for self-supply, the proposed photovoltaic and BESS combination is an affordable option, but Martinez-Bolaños sets that the electrochemical batteries costs for Brazilian consumers must decrease to enable the viability of multi-source systems. The energy sources combination is a advantage for consumers in emerging economies, increasing the advantage of regular technologies to afford the BESS implementation.

Reduced costs to buy a BESS is an advantage cited by Lin e Wu [16], and the authors developed an optimization for energy prices to increase the viability for final consumers located in China. The authors describe the regulated sector in the country, as a parameter to ensure universal access to electrical energy. The access to the infrastructure, and the tariffs variation condition a more viable BESS usage. The main concern, according to the authors, is to enhance the possible gains for stakeholders, which occur when the costs of the energy supplied by the grid are lower after the system implementation.

Santos [17] and Thomé [18] analyze two viability scenarios for a BESS implementation in Brazil. Santos [17] analyses the deployment of photovoltaic infrastructure to supply a building with and without the usage of a BESS as a complementary source. The focus is cost reduction and enhancing the deployment of the photovoltaic panels. The energy supplied by the panels charges the BESS, which is discharged during peak hours, through a time-shift strategy. The work defines the estimative of demand parameters to customize the solution and address the full consumer's demand. As a result, the costs to deploy a similar infrastructure must decrease in the country. The author also highlights that the costs are a gap that hinders the entry of new distributed generators.

Thomé [18] studies the values of tariffs and the expected demand for consumers connected to the medium-voltage network to check the deployment of batteries. The author establishes the costs to buy the infrastructure and its expected lifetime to analyze the viability of a consumer located in three different areas; the work analyses the economic viability through parameters as Net Present Value (NPV) and In- ternal Rate of Return (IRR). As a result, the work establishes that the replacement of the grid during peak hours is not viable due to the excessive costs of the infrastructure.

The economic viability of a technology-implementation project is important to point out the benefits and values for stakeholders, due to the most valuable parameters in a project evaluation: costs, time, and scope. Despite the interest in the affordability of these projects through the economic perspective, the strategy to install technology with the focus to decrease the negative impacts of the energy sector functioning must be broader, with the addition of social and ecological as vital dimensions. So, the goals for this kind of project guide the replacement or reduction of non-renewable energy sources.

The project leads to a technology-access approach, i.e., considering that the affordability of the BESS deployment enables the increase of consumers participation and a cleaner energy matrix. Thus, the entry of BESS is analyzed through a participatory perspective, instead of a profit perspective. A sustainable project has, as a result, a sustainable product or applies sustainable practices, but it must be socially and environmentally acceptable as a process [19].

III. Overview of Energy Sector for Technology Addition

The 90's decade characterizes institutional reforms and privatization processes in Brazil. The first reform focused on increasing competitiveness and privatizing companies, and the second reform established conditions to expand the sector, creating governmental enterprises able to plan and manage the expansion process

[20]. The unbundling of generation, transmission, and distribution processes provided by the same company is one result of the last reform, and the setting of regulatory agency as the responsibility to regulate prices and services provision.

In Brazil, the electrical sector is regulated by ANEEL (Agência Nacional de Energia Elétrica), a public agency subordinated to the federal government. The agency is responsible to establish rules about service provision, ensuring that providers and consumers fulfill the established norms. In Brazil, the entry of BESS strengthened after the public call of the regulatory agency ANEEL, which focused on encouraging projects related to storage technologies: the public call was set in 2016 and allowed different Pilot Projects implementation in the country. Currently, there are no norms about the entry of energy storage systems in the country. The energy sector deploys 84% of renewable energy sources, composed of hydro, wind, and biomass - 61.83%, 10.70% and 8.76%, respectively- opposed to 16.78% of non-renewable energy sources [21]. It is expected that the energy demand will grow in the future, followed by demographic growth and urbanization; besides, the energy demand depends on the economic scenario for the following years. Despite these data, the power generated by hydro sources is expected to remain at the current rates, and thermoelectric and non-hydro sources are expected to increase [22].

The growth of solar and wind power may lead to more distributed generators, as a natural consequence of the position of these sources in the grid. The entry of distributed generators is linked to reducing infrastructure costs and reducing loss of energy, increasing energy security, and meeting the demand. Besides, the growth of distributed generator carries to a new role to consumers and establish conditions of distributed generators through normative resolutions 506 [23], 414 [24] and 482 [25]. The quoted normative resolutions set conditions for mini and micro-generator to install their infrastructure, and the possible conditions for economic compensation in case of energy dispatched to the grid.

Resolution 414 classifies consumers according to demand and installation types: consumers A consumers supplied by a voltage equal or superior to 2,3 kV or attended by underground systems - and charged with binomial tariff, and consumers B - voltage limits lower than 2,3 kV- with flat rate tariffs [24]. Normative Resolution 733 [26] establishes three periods - peak, intermediate, and off-peak - for all consumers, that can change their profile for an hour-adaptable tariff named White Tariffs (Tarifa Branca) [26]. The White Tariff encourages consumers to change their consumption patterns to reduce costs. The country implemented the tariff in 2018, but it is available for all consumers since January 2020. The consumer must adhere to this tariff model, and he can revert to the previous tariff in case of a non-advantageous situation. The new tariff is not available for public illumination and low-income consumers [26].

Normative resolution 482 [25] establishes the parameters for micro or mini distributed generators connected to the grid and states the conditions for these producers in the local energy sector, including financial compensation [25]. Besides norms for distributed generators, the agency also describes the boundaries be- tween the distribution companies and consumers/generators. Normative Resolution 414 [24] establishes the physical limits for the grid and consumers, setting responsibilities related to the infrastructure maintenance and operation, and supply assurance.

Normative resolution 506 [23] describes the rights and obligations for distribution companies, stating their services provision limits and how consumers must reward the companies according to energy-related services supply. The Normative Resolutions establish that power distribution companies are not allowed to manage or operate the infrastructure behind the meter, and state that these companies are not allowed to provide services regarding generation.

The agency and other stakeholders are discussing the most affordable fashion to compensate the distributed generators for the services provided. For distributed generators with an amount of 5 MW of installed capacity, classified as mini or micro distributed generators, the reward is a discount in the bill by the power dispatched to the grid. Based on the presented conditions, generators can provide time-shifting, capacity, and ancillary services for tension and frequency control services. The tariffs and the rewarding of the distributed generator are a current subject in the country, and changes in the resolutions are expected in the short term.

The current stage of renewables deployment and distributed generator encouragement in the sector establish opportunities to design a new field for BESS implementation in the country. Since the rules and resolutions are being discussed and developed, the stakeholders may take advantage of the current stage to contribute with ideas and technical skills. The current stage of the technology implementation highlights that technical teams must be trained, and information regarding the technology implementation and access must be available. The management of knowledge and the training of professionals must be encouraged, establishing a new supply and technical chain for suppliers and manufacturers in Brazil.

The reduced number of suppliers and manufacturers in Brazil highlights the high dependency on technology imported from other countries, which implies higher costs and difficulties met during the purchasing process. The absence of government programs on access to clean and secure energy, as established by the United Nations as fundamental steps towards a sustainable future [27], and access to technology may delay the entry of BESS in the country. Since the early eighties, the federal government has supported programs related to energy efficiency and the universalization of resources. These programs are concerned with changes in consumption patterns and intense urbanization process [28].

Despite the great importance of efficiency for greener practices, the focus of these programs is grating labels regarding appliances functioning and energy conservation; as an example, PROCEL (Programa Nacional de Conservação de Energia Elétrica) grants labels for efficient equipment and services, which may lead to more sustainable habits and energy conservation [29]. As another example of governmental initiative regarding efficiency and renewable integration, PROINFA (Programa de Incentivo a Fontes Renováveis) encourages new and independent projects that generate energy with renewable sources [30]. Despite the efforts in addressing energy efficiency policies, long-term scheduling is not established by the responsible entities. Besides, the focus on the residential sector limits the potential of these programs, which are established after events that affect the energy sector.

As a factor that affects the sector, environmental issues may influence the fashion generation and efficiency programs are addressed. The country must cope with environmental challenges itself, addressing how the energy demand is addressed. International agreements enclose the carbon emission for the future years, alongside public pressure concerns to the preservation of the environment. These two factors enhance requirements to reduce negative impacts for the internal energy sector along with a more renewable agenda. The environmental agenda works along with economic and social scenarios that enable the deployment of innovative technology or efficiency conditions. The three parameters establish the conditions on future demand and its supply.

Despite the significant importance of a renewable agenda and the decarbonization of the energy sector, there are no programs in Brazil focused on greener energy sources and innovative technology encouragement. This scenario delays the organization of a supply chain for technologies, which include the BESS and other technologies for the energy sector, including the establishment of a specialized industry in the country. The strict access to technology also inhibits the development of specialized professionals and the availability of information and communication channels.

The information regarding the BESS deployment in Brazil and the status of the technology in other countries must be considered by stakeholders. Changes in the external or internal scenario enable the prioritization of steps in a BESS deployment project, as barriers are solved, or opportunities are enhanced. The next step is classifying the information into external or internal parameters to achieve the established goals. The gathered information is grouped into advantages and disadvantages of the country in comparison to other countries, described by the internal scenario, and information that may encourage the technology deployment as described by the external scenarios.

The described configuration allows the evaluation of the current scenario in Brazil and establishes a strategy for the system deployment. The strategy encompasses the development of a process that reinforces the advantages and points out the conditions that must be changed, minimizing the risks for stakeholders. As a result of this analysis, steps, and tasks, manageable through time, must be established.

The manageable steps describe the market and business parameters that must be addressed during the BESS deployment, reinforced by the legal and human resources skills essential to entry and performance. Parameters of the technology itself must connect these subjects, establishing how the activities must be performed. As a result, the steps classify the terms into Market, Business Model, Technology, Resources and Skills, and Regulation layers [31].

Technology terms address how investments and research activities are set to put in place the new system, describing how research and information broadcast can orchestrate the technology entry. This layer establishes the technical approaches for innovative technology, describing activities for existing systems evaluation and knowledge enhancement. The costs related to BESS purchasing and maintenance are high, which may hinder access to most distributed generators. The Taxes and Incentives terms gather manageable actions regarding costs and encouragements for BESS deployment, which may lead to access of new stakeholders to the system and the expansion of the concurrency. These actions are related to tax discounts and subsidies, based on governmental support, to cleaner and improved generation sources. The costs and the entry of the technology imply how the energy-based services are provided, which lead to business and new processes evaluation.

Business Models covers the terms related to the expansion of the distributed generation, establishing how new commercial models must deal with strategic planning, market share, processes building, and performance. The statement of a new business model must manage the clients' profiles and demands, the offer of new services, and niches and rules setting, encouraging a new supply-chain creation and distributed generators entry in the sector. The information regarding consumers' profiles is vital to ensure that new Business Models fulfill their demands. To gather operational and managing information, the work establishes that the layer Pilot Project encompasses terms regarding data acquisition and analysis.

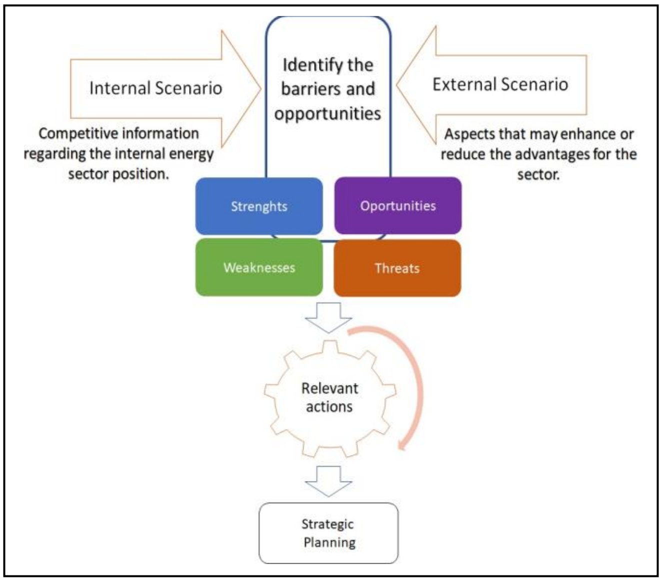

Fig. 1. *Method for the roadmap development*

Due to the importance of new information gathering and disclosure, a layer focused in Communication terms is inserted. This layer copes with information publicizing and stakeholders' engagement. Another focus of this layer is to enable the training of specialized crew and the development of technical files through information exchange channels. The newness of the technology leads to crew training, which terms are detailed in the Resources and Skills layer. The layer presents crew building, technical skills management, and a new supply chain formation.

The chain of the specialized crew, suppliers, and manufacturers are terms described in the Technology and Incentives layer. The terms refer to the risks of imported technology - deadlines and costs -, lack of subsidies and government programs, and the disadvantage of national industries. Besides, the terms presented in this layer affect the scalability, information gathering, and disclosure; the high dependency of imported technology implies in business models, supply chain, regulatory parameters able to cope with external market requirements. The Market layer presents the terms corresponding to cultural changes required, such as constant releases for BESS entry encouragement, and the definition of communication channels-websites, help-desk, specialized media, technical committees, and conferences.

The Market layer details actions that may bolster the technology entry through campaigns and federal programs focused on developing internal production or enhancing the supply chain. The Market layer establishes how to install the required actions through the current market standard. The layer presents changes regarding market status and governmental actions that may encourage the deployment of BESS. In addition, government and agencies must develop standards and regulatory terms focused on management and operation of the BESS. The Regulation issues map barriers of regulatory terms, specifying rules for implementing and managing a storage system, describing stakeholders, and coping with new services supply. These issues set the responsibilities and rights for all stakeholders' responsibilities, which may include management and maintenance rules, security, and environmental questions.

Figure 2 shows the predicted activities organized into layers, according to the previous text. The activities are manageable through the established periods - short, medium, and long terms -, following relevant aspects gathered from external and internal scenarios.

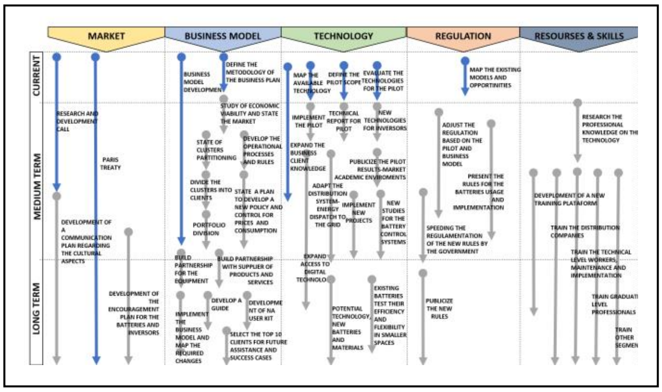

Fig. 2. *Framework for an energy storage system entry*

IV. ACTING FOR A BATTERY IMPLEMENTATION

One approach to encourage BESS deployment is the replacement of Diesel generators, a non-renewable and less efficient energy source. Commercial and industrial consumers use commonly solutions based on Diesel generators as alternative to cope with costs or increase the supply reliability. The employment of Diesel generators growth during the rise of energy tariffs or water scarcity: around twenty thousand Diesel generators were deployed in 2015 in São Paulo state [32]. This fact contributes to a high deployment of non-renewable energy sources in the country, 4.9% of Diesel and fuel oil [22].

A BESS-based solution may be an option for these groups, in case it is an affordable solution. The case report evaluates the implementation of a BESS as an alternative for a consumer connected to a medium voltage grid. The consumer is a service station located in Jundiaí, a city near São Paulo, and the station includes a gas station, an electric vehicle charging station, and a restaurant in the location, both working 24 hours a day. According to the resolutions, the tariff sets peak and off-peak periods, complemented by a single tariff for its contracted demand. The goal for this consumer is to reduce its costs during peak periods - three-hour interval that starts at six p.m. and ends at nine p.m. daily, besides weekends and holidays - through the employment of a BESS as an alternative energy source during the period. The energy storage system must supply the service station during the peak period or power loss conditions, with a diesel generator set as a backup generation source. The energy supplied from the grid attends to the consumer during off-peak periods; during these periods, the battery is charged.

Jundiaí is located in concession area of CPFL (Companhia Paulista de Força e Luz) formed by 234 cities, most of them are populated, industrial and technological centers. Based on the consumption rate for 12 months, the potential consumption of diesel generator in the area was measured: it was established the consumption of consumers classified as A4 subgroup - tension required from 2.3 kV until 25 kV -, i.e., with a similar profile of the consumer where the BESS is implemented. The consumption is set as the mean of the measured demand through the period and the mean of the demand during the peak period [33]. The results show that 3,000 clients deploy diesel generators during peak periods, which leads to 0.7 GW of capacity [33]. Brazil accounts for 264,732 distributed power plants, with 3,322,128.29 kW of installed capacity, and 30% of the total distributed power plants are implemented in commercial-class consumers [34], showing the growing interest in new and resilient energy sources.

The tariff is stated into a three-part determination that refers to the amount of energy generated, the transport of the energy until the consumers - includes transmission and distribution costs-, and taxes for the sector, non-manageable costs, and transferred to consumers. The tariff is categorized into TUSD (Tariff for the Distribution System Usage) - a single value that concerns the usage of the distribution infrastructure - and TE (Energy Tariff) that refers to the value of the energy consumed and employed to set the monthly income. The taxes for the consumers are determined by the local government and state: local taxes on the circulation of products and social taxes are parts of the tariff for a Brazilian consumer. The rise in rates and taxes depends on economic parameters that change through time. The IPCA (National Wide Index for Consumers Prices) measures the impact of inflation on assets and services, and it enables the tariffs' expected values establishment.

The viability study considers the tariff's expected variation and along with purchasing and maintenance costs. The analysis establishes four different scenarios: a Diesel Generator, BESS - NCA (Lithium nickel cobalt aluminum oxides), and LFP (Lithium Iron Phosphate)- and with the mix of BESS and Diesel Generator as replacements for the Grid during peak periods. As a comparison, the scenario with the full supply through the grid is the Base Case for the study. The cost reduction during peak periods may encourage the BESS solution affordability for the analyzed consumer. The study sets 25 years as the life cycle of a BESS. Figure 3 shows the Cash Flow for the Diesel Generator: differential cash flow for the first year is negative, due to the recent investments in obtaining the generator. After the second year, the differential parameter is positive. The positive values for the differential cash flow define that the consumer may reduce costs, due to higher values of the energy supplied by the grid and the expectations of tariffs increase for the period, in comparison to operational and maintenance costs of the Diesel Generator. Further analysis sets that NPV is positive, showing the economic viability of the Diesel Generator as a replacement of the Grid during peak hours.

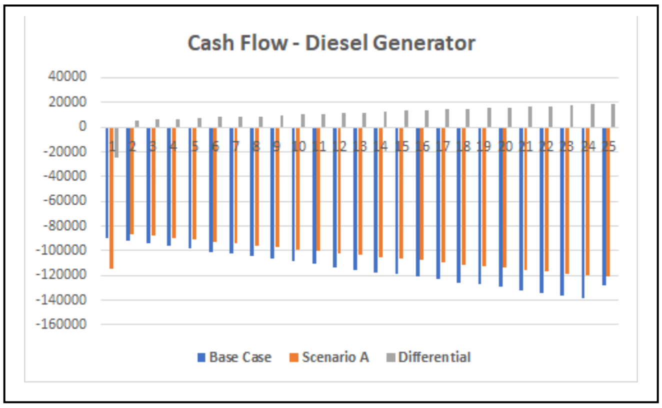

Fig. 3. *Cash Flow for Scenario A*

For the second scenario the grid supplies the demand during off-peak periods and the BESS -based in LFP-batteries - attends the demand during peak hours. Figure 4 shows the Cash Flow for the grid and BESS combination. The average value of the differential cash flow is negative for the first year, due to the costs to buy and adjust the system. After the second year of operation, the average values of the differential cash flow are positive since the infrastructure replacement does not occur.

The positive differential cash flow points out that the combination of the sources may be viable for the consumer as a replacement of the grid during peak hours due to costs reduction. The average cash flow for the first year is higher in comparison to the Diesel Generator scenario (Scenario A): the value is 80.75% higher, and the differential cash flow is 3.43% lower at the end of the lifecycle due to capacity loss and efficiency of the BESS. The analysis of the NPV and IRR sets that the probability of negative NPV is high, with 95% of certainty. The sensitivity analysis establishes that parameters related to the system buy, maintenance, and operation must decrease 56.5% to achieve the break-even point.

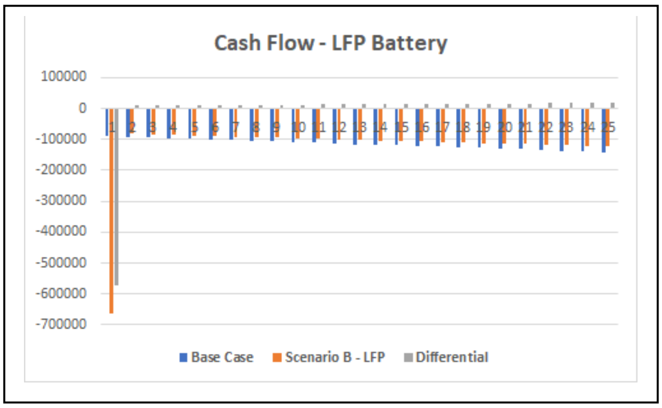

Fig. 4. *Cash Flow for Scenario B*

Figure 5 shows the cash flow for the referred scenario. The cash flow is like the LFP scenario, due to the batteries' performance characteristics. The NVP for this scenario is negative for the period, which states that the replacement of the grid during peak hours is not viable for an NCA battery solution. This analysis endorses the high probability (97.5%) of negative values for the IRR, due to the sum of the lower cash flows in comparison to the initial investment. The sensitivity analysis establishes that the values for the probability distribution function must decrease 41.6% to achieve the break-even point.

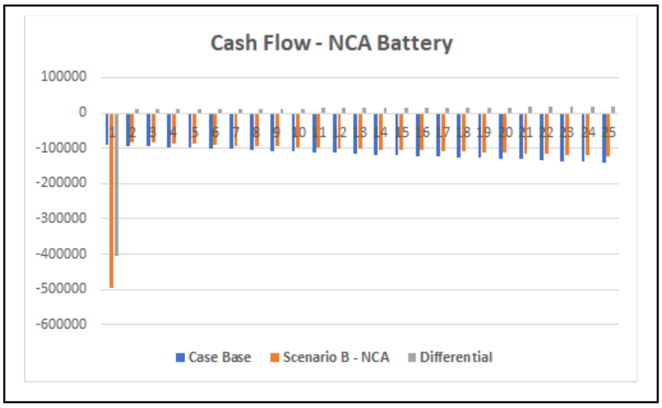

Fig. 5. *Cash Flow for Scenario C*

The analysis of the previous scenarios establishes that the Diesel Generator is the most affordable replacement of the grid during peak hours. Despite the excessive costs to buy and maintain the Diesel Generator, the tariffs values and their expected adjustments encourage the deployment of alternative energy sources during peak hours.

The tariffs and the expected variation and adjustments contrast with scenarios based on BESS deployment. Scenario D considers the combination of the grid, BESS - NCA battery-, and the Diesel Generator. During off-peak periods, the grid supplies the consumer, and the BESS is charged, and during peak hours, the BESS supplies the consumer. The Diesel Generator is employed in case of unavailability by the BESS. Figure 6 shows the cash flow for the three sources scenario. The average value of the differential cash flow is negative for the first year, due to the recent investment in the infrastructure. The required investment is lower compared with LFP-batteries without subsidies, due to the lower costs to purchase the Diesel Generator compared to the costs to acquire the batteries analyzed in this work.

After the second year of the period, the average value of the differential cash flow is positive, due to the impacts of the grid replacement during peak hours and the savings in the energy bill. The positive results are lower when compared to the BESS scenarios - scenarios B and C-, due to maintenance costs of the Diesel Generator. The average value for NPV is negative for this solution. The probability of negative values for NPV and IRR are high, due to lower values of the average differential cash flows when compared to the initial investments. The break-even point analysis states that costs to purchase the BESS must decrease 48.3% to reach the break-even point, with a 50% probability.

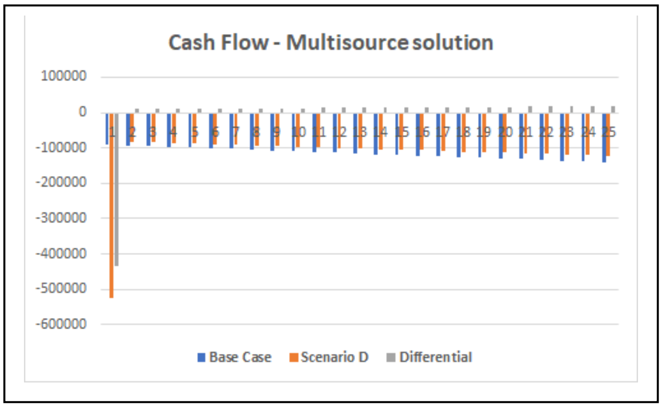

Fig. 6. *Cash Flow for Scenario D*

The viability study establishes that the Diesel Generator is the most affordable replacement for the energy supplied by the grid. The inflated costs to purchase and to maintain the Diesel Generator are an affordable alternative for this group of consumers, in comparison to the tariffs and the expected variation for the period. The values to purchase a BESS are a barrier to these consumers, and a strong and operative supply chain reinforces the access to Diesel Generators, including maintenance and operational skills and crews.

The combination of a Diesel Generator and a BESS reinforces the inflated costs regarding storage systems purchasing and maintenance. Scenarios B and C reinforces that the BESS is not an affordable option, from an economic perspective, to replace the grid during peak hours. From an environmental perspective, the scenarios point out that Brazil must encourage the deployment of renewable sources, but the input of BESS requires significant changes in the local energy sector.

The absence or decrease of governmental programs focused on technology diffusion and modern energy are significant barriers. The proposed roadmap considers programs or a governmental agenda for cleaner technologies in the lower layers, and the monitoring of environmental agreements are steps mapped as well. Since incentives and subsidies are parameters associated with the success of a more renewable agenda [2], although the absence of a governmental agenda delays the establishment of energy policies and strategic planning as well.

The presented set of factors also highlights the role of institutions: the agency of institutions and consumers' engagement are valuable parameters in these scenarios. The analysis, at this moment, does not consider social and environmental parameters for the viability study, but society participation and the definition of modern consumers' roles [35]. These concepts highlight flaws regarding communication and technology exchange for emergent economies.

The access to technologies and the initial investments highlights the asymmetry of emergent and developed economies. The establishment of a supply chain for emergent economies is a result of these conditions: the strengthening of the local industry, encouraging the development of technology and research, and the implementation of Pilot Projects are current demands for the local sector. The development of these factors is described into Market and Business Model layers, but actions regarding information and resources allocation are steps for Regulation and Resources and Skills layers.

The development of projects by academia and institutions is a step for the input of BESS as well. Thus, political, and societal interests must be aligned to encourage the deployment of BESS as a solution to the country, reducing fossil fuels dependency and establishing sustainable goals. The number of consumers and capacity points out that there is a significant opportunity to reduce the Diesel Generators usage as an alternative to reduce energy costs. The data shows the consumers' openness to improved solutions to ensure their continuity in business but does point out their readiness to solutions with reduced environmental impacts.

V. Conclusion and Future Works

The decarbonization of the energy sector is a crucial step in mitigating the impacts of climate change. As consumption patterns and processes must shift, the industry is facing new challenges. Although BESS have allowed for a transition scenario, access to this technology is not universally available. Therefore, there is a need to create a map that presents a path towards a more sustainable energy future, while also taking into account the technological, economic, and social disparities between countries. This map would provide stakeholders with manageable steps towards a more sustainable energy system that is accessible to all. By working together and taking these steps, we can create a more equitable and sustainable future for generations to come.

In managing external scenarios and issues, it is common practice to separate them into individual layers to better understand and address them. However, it is important to note that these layers are not entirely independent and that addressing one layer may impact the management of others. This is especially relevant when implementing technology that can enable an evolutionary scenario for the local energy sector and stakeholders. While this technology presents many opportunities, it is crucial to address any underlying issues as primary requirements for all parties involved. By doing so, we can ensure a more holistic and sustainable approach to managing external scenarios and issues.

This study focuses on the economic viability of using a BESS to replace Diesel Generators as an alternative energy source. The analysis takes into account the tariffs values and charges associated with BESS deployment to evaluate its feasibility. The study concludes that the high costs associated with purchasing BESS are a significant barrier to its deployment in the country. Moreover, the tariffs are subject to changes in the energy matrix, which is increasingly reliant on renewable sources, leading to significant variances. The study also discusses the current compensation for distributed generators, which may lead to higher costs for stakeholders but does not necessarily bolster the deployment of BESS. These findings underscore the importance of considering the economic viability of alternative energy sources, as well as the need for policies that incentivize the deployment of BESS as a viable and sustainable solution for energy production.

Energy policies that focus on technology can create new compensation and tariff models for distributed generators, which may encourage the adoption of BESS in the energy sector. This process may also encourage the development of the supply chain and strengthen the local industry sector. Although the economic analysis highlights the barriers to BESS deployment, the proposed roadmap remains a valuable tool for stakeholders to navigate the process. The economic analysis does not invalidate the roadmap, which can help stakeholders identify opportunities and overcome challenges in the deployment of BESS.

The next steps of this research focus on evaluating methods that make BESS an affordable technology for consumers through a business model that allows them to enter the energy sector as multiple energy sources solution. Another important aspect is governance, which needs to facilitate consumers' entry into the energy sector. The research also considers social and technical governance for BESS solutions and the role of distributed generators during the transition scenario. The evaluation of environmental and social parameters is also part of the future research steps. These efforts will contribute to a more comprehensive understanding of the feasibility of BESS deployment and its potential impact on the energy sector.

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