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Expert Survey on Energy Storage Systems: regulation and policy from an Indian power sector perspective

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Abstract

A survey of Indian power-sector stakeholders on the subject of Energy Storage System (ESS) policy and regulatory issues is presented. The survey is divided into four sub-themes: the need for ESSs; ESSs in a network context; ESSs in the market; and ESSs in innovation. Respondents support the need for dedicated ESS regulation, including a definition of ESSs. In terms of networks, respondents support unrestricted ownership, and the development of dedicated grid connection standards and the provision of ancillary services for the network by ESSs; this would allow their participation in wholesale energy markets. However, opinions diverge on the level of ESS regulatory oversight needed for grid investment deferral. As far as power markets are concerned, respondents agree on the need for updating bidding formats, special treatment for ESSs regarding grid access charges to eliminate market entry barriers and to incentivise the operational versatility of ESSs. However, opinions diverge on the appropriate compensation mechanism to be applied for services provided by ESSs. There is an agreement on supporting innovative ideas such as P-to-everything (P2X) conversion and the use of regulatory sandboxes for enabling ESS.

Keywords

Energy storage systems, Energy Policy, Expert Survey, Power Markets, Power Grids Regulation.

1. Introduction[*]

India has set itself an ambitious target: 175 GW of renewable energy capacity by the year 2022 (NITI Aayog, 2015), and renewable energy capacity will only increase thereafter. However, the intermittent nature of renewable resources also raises issues related to power availability, power quality and network stability. A power system based on intermittent renewable energy would require flexibility to balance supply and demand. Storing electricity is one way of providing system flexibility. The growing commercial viability and the development of various energy storage systems has opened up the possibility for electrical energy to be used some time after it has been generated. Therefore, it could be said that while "copper wires" transmit electricity across space, storage transmits electricity across time.

In the Indian electricity sector context, Energy Storage has been identified as a crucial technology for an increasingly renewable-based power system by policymakers, regulators and other stakeholders. According to NiTi Aayog, as of January 2020, India will need 50 GWh of energy storage capacity over the next two-and-a-half years (Joshi and Koundal, 2020). However, India currently does not have dedicated regulatory guidelines or policies on Energy Storage System (ESS). Furthermore, the current research on ESSs is generally focused on technical aspects and ESS applications.

Across the world, several types of storage technologies have been proposed, tested and are currently being implemented. Guney and Tepe, (2017) classify energy storage as chemical (e.g., hydrogen, Synthetic natural gas), electrochemical (e.g., battery, fuel cells), electrical (e.g., capacitors), mechanical (e.g., flywheels, compressed air energy storage) and thermal systems (e.g., sensible heat system, latent heat system). As of today, hydroelectric power plants with reservoir and pumped hydroelectric storage – classified as mechanical storage – account for most storage capacity. These traditional storage technologies are not considered within the scope of this study.

ESSs can participate across different segments of the electricity value chain from generation to consumption, at both centralised and decentralised levels (Lichtner et al., 2010; Mohamad et al., 2018). These devices can: provide ancillary services; participate in wholesale markets (as both buyers and sellers); can also be used for congestion management (IRENA, 2017a, 2020; Meeus and Bhagwat, 2018); and can be used for 'behind the meter' bill optimisation. Furthermore, ESSs can potentially substitute some grid investments. Thus, the functional versatility of batteries truly makes ESSs a 'jack of all trades'. However, this functional versatility also makes it extremely difficult to define them in the current regulatory framework.

This paper analyses the policy, regulatory and market design dimensions of the ESS debate in India from a power sector perspective using an expert survey. The paper presents the outcomes of the expert survey and consequently the views of selected experts and stakeholders from the India power sector on the topic of ESSs. The paper does not make any judgement on outcomes, but limits itself to providing readers with insights from stakeholders working within the Indian power sector.

As the first step, in structuring a debate on ESSs, an expert survey was planned. The survey aims at understanding the views of Indian stakeholders on key policy, market design and regulatory issues within the four sub-themes based on a review of relevant literature. The contributions reviewed to develop this survey were: AEMC, (2016, 2015); Anaya and Pollitt, (2015); BATSTORM, (2018); Bhatnagar et al., (2013); Castagneto-Gissey and Dodds, (2016); CERC, (2017); European Parliament, (2019); FERC, (2018); Fitzgerald et al., (2015); IRENA, (2020, 2019a, 2019b, 2017b, 2017a); Jain et

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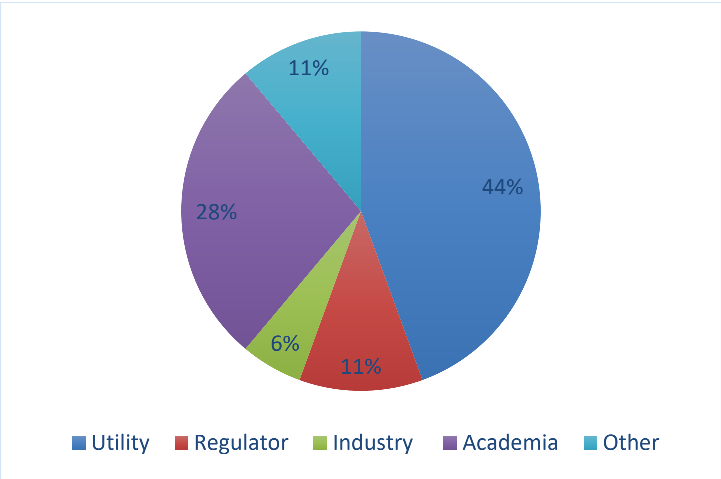
al., (2013); Kuldeep et al., (2016); Meeus and Bhagwat, (2018); NITI Aayog, (2019); NREL, (2019); Potau et al., (2018); RGI and CAISO, (2019); Ruz and Pollitt, (2016); Schittekatte et al., (2020); Sioshansi et al., (2012); Walawalkar et al., (2007); and Woodman and Baker, (2008). Appendix-I provides a brief description of each study. Furthermore, deeper research is envisaged in the future on each of the sub-themes in the Indian context, based on an analysis of the questionnaire results.

2. Survey structure

The survey was conducted anonymously, and the respondents included experts from energy utilities, government/regulatory agencies, industry, academia, think tanks and market operators and industry organisations (see Figure 1). The respondent mix was weighted, somewhat, towards utilities, and academia. To ensure the relevance of the results, the respondents invited to participate in the survey were carefully chosen. The experts were selected so as to ensure a good professional spread from the various stakeholder entities. Furthermore, during the selection process, importance was given to the respondents' years of experiences. The professional power-sector experience of these experts ranged from 9 years to 36 years, with an average of 21 years. Finally, another important consideration during the selection process was the respondent's understanding of ESSs either through practice or education. The survey was conducted between 6 August 2020 and 9 September 2020. Eighteen participants completed the survey.

Figure 1: Respondents by industry segment



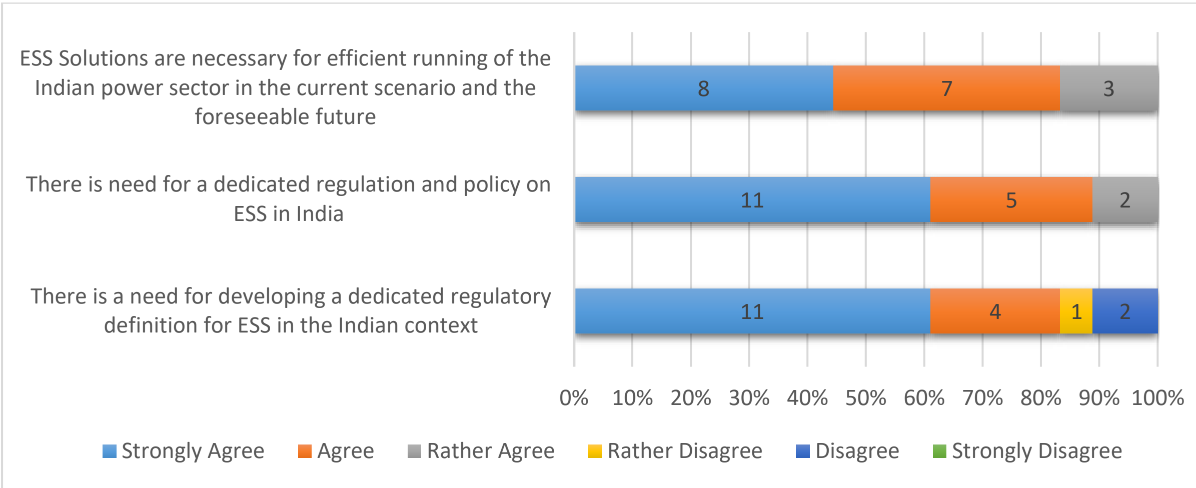
The survey was divided into four sections. The **first section** focused on general questions such as the need for developing **dedicated regulations and policies** for energy storage systems. The **second** and the **third section**s focus on the linkage of the ESSs with, respectively, the power **networks** and the power **markets**. Finally, the **fourth section** focused on regulatory and policy level **innovation** in the ESS context. These themes are chosen with the aim of covering the fundamental questions that arise about the implementation of ESS technologies from a policy and regulatory dimension. Firstly, before delving deeper into the relevant issues regarding ESSs, it is crucial to gauge the need for ESSs and ESS specific regulations in the Indian power sector. ESSs are expected to have a significant impact on two fundamental pillars of the power sector from the onset of its implementation namely, networks and markets. Finally, given rapid innovation in the sector it is important to consider this dimension to ensure some level of 'future proofing'.

A Likert scale approach was used in designing the questionnaire (Robbins and Heiberger, 2011). Consequently, the responders were presented with a statement for which they had to choose their level of agreement. Respondents had to choose from six multiple-choice options, namely: Strongly Agree, Agree, Rather Agree, Rather Disagree, Disagree and Strongly Disagree. There were sixteen questions.

3. Need for ESSs in India

Based on the literature review of the documents described in Appendix I, the first section of the survey identified three fundamental overview questions: **1)** whether there is any need for ESSs in the Indian power sector; **2)** whether there is a need for dedicated regulations and policies for ESSs; and **3)** whether there is a need for the development of a dedicated regulatory definition for ESSs. Figure 2Figure 1 provides a summary of the main results.

Figure 2: Responses to the survey questions on the need for ESSs in India



Each power system has its peculiarities and requires customised solutions related to the issues faced by a given power system. India, too, would require a customised solution for the transformation of its power system. Thus, the first question that needs to be answered in the Indian context is, whether ESSs are necessary to efficiently run the Indian power system in the current scenario and for the foreseeable future. 44% of the experts strongly agreed, 39% Agreed, and the rest "rather agreed" on the need for ESSs.

Currently India does not have dedicated regulatory guidelines or policies addressing ESSs. ESSs are functionally versatile and thus they can participate across different segments of the electricity sector. However, the functional versatility of batteries makes it extremely difficult to define them in the current regulatory framework so as to fully unlock their potential (Meeus and Bhagwat, 2018). Consequently, it may be necessary not only to develop a regulatory definition for ESS, but also to develop a dedicated regulatory and policy framework and its inclusion in other related regulations and policy. Thus, we asked our experts to what extent they agreed on the need for dedicated regulation and policies on ESSs in India. The results indicated an explicit agreement on the need for developing dedicated regulation with 61% strongly agreeing, 39% agreeing to the statement and the rest "rather agreeing". There was similar agreement on the need for the development of a dedicated regulatory definition for ESSs in the Indian context. 61% of respondents strongly agreed, 22% agreed or "rather agreed" with the statement. Note that 17% of respondents disagreed with the need for a definition.

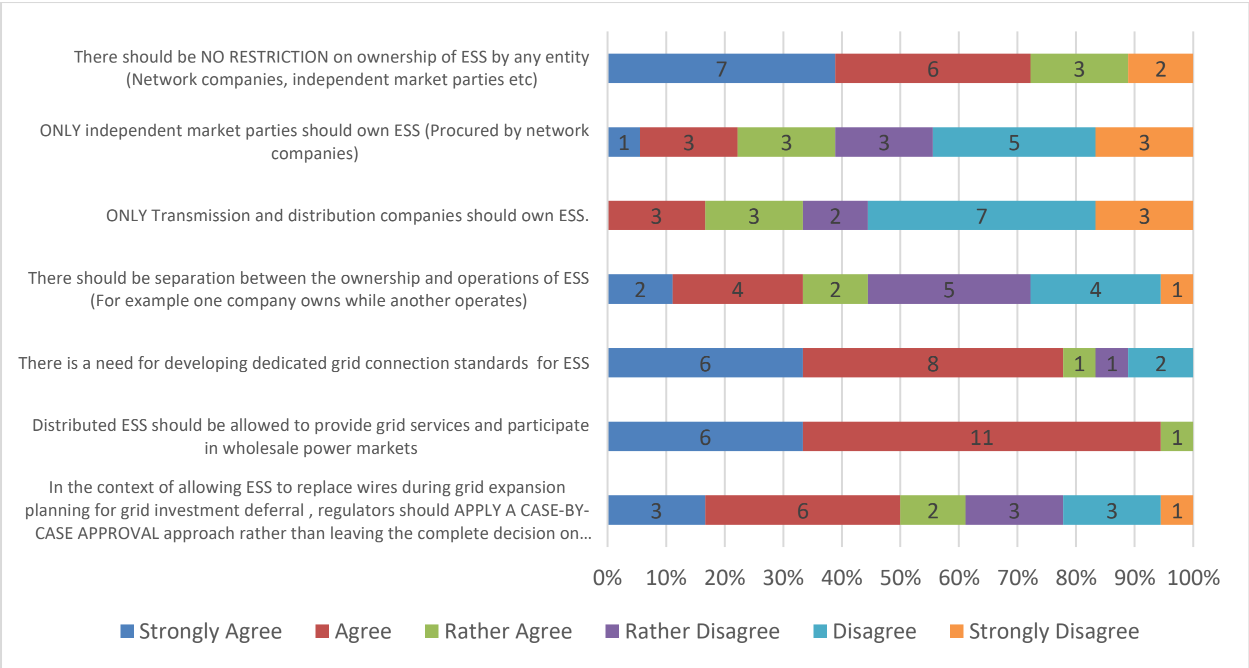
The approach for developing this definition of ESSs would depend on the context in which it is applied. For example, one approach might be to define ESSs within a general statement. This approach is used in the European Union's recent recast of the Electricity Directive (European Parliament, 2019). There, energy storage is defined thus: "'*energy storage' means, in the electricity system, deferring the final use of electricity to a moment later than when it was generated, or the conversion of electrical* *energy into a form of energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electrical energy or use as another energy carrier".* Another approach might be to create a list specifying the inclusion or exclusion of ESSs. This approach has apparently not yet been applied to energy storage, but would entail identifying and specifying the exact technologies to be included in the list. For example, if you consider the classification of Guney and Tepe (2017), the list might include: chemical (e.g. hydrogen, Synthetic natural gas); electrochemical (e.g. battery, fuel cells); electrical (e.g. capacitors); mechanical (e.g. flywheels, compressed air energy storage); and thermal (e.g. sensible heat system, latent heat system) technologies. A third approach would be the modification of the current definition of supply and demand to accommodate storage technologies. The development approach for the definition of ESSs is not covered by this paper.

There is, then, in the expert survey a perceived need for ESSs to run the Indian power system efficiently. Furthermore, there is also, the experts think, a need for developing dedicated regulation for ESSs, which includes a regulatory definition of ESSs. Further discussion is needed on the appropriate approach for developing this definition in the Indian context.

4. ESSs in the network context

Four key issues identified during the literature review were addressed in the context of ESSs from the power network perspective. These might become relevant to India as they have become important in other countries. The issues identified were: 1) ownership of storage; 2) grid connection standards for ESS; 3) provision of ancillary services to the network by distributed storage and allowing their participation in wholesale energy markets; and 4) use of ESSs for grid investment deferral. The main results are presented in Figure 3. Note that four separate questions were asked in the context of ownership to understand the view of the respondents on different ownership models, as well as on the splitting of ownership from ESS operation.

Figure 3: Responses to survey questions on the network context of ESSs



An important debate on advanced liberalised markets has revolved around ESS ownership. Generally, ownership could be defined, as the right to own, develop, manage and/or operate ESS. On the one hand, it might be argued that ESS grid ownership could help in improving operations, mitigating any market power issues and deferring investment. On the other hand, from a competitive market perspective, it might be argued that ESS grid ownership could distort the market. There would be preference for their own assets over service procurement, especially if a competitive approach for flexibility provisions is implemented.

There are different approaches to ESS ownership, such as ownership by network operators and ownership by independent market parties (ESSs purely as a service). From Figure 3 we see that our experts would prefer there being no restriction on ESS ownership by any entity (network companies, independent market parties etc.).

According to the literature reviewed, delinking of the financial ownership of the battery and the handling of the operational aspects within the definition can also be usefully considered as an option. Interestingly, it is observed that, on the question of separating ownership and operation of ESS, opinion is split almost evenly with 45% agreeing and 55% disagreeing to various degrees. Thus, there is scope for further discussion and in-depth analysis on this topic (see Figure 3).

We have established that energy storage is a unique construct within the power system due to their ability to withdraw, store and inject electricity rapidly. In the literature, ESS integration has raised concerns regarding network security. This has led to a discussion on whether the current grid standards are sufficient for addressing these network security concerns or whether there is a need for developing a dedicated grid connection standard for ESSs. The respondents appear to agree on the need for developing dedicated grid connection standards for ESSs (33% strongly agree, 44% agree, 6% rather agree, 6% rather disagree, 11% disagree). (See Figure 4). This indicates that there are concerns about ESS impact on the secure operations of the network.

Distributed ESSs, especially as part of Distributed Energy Resources (DER), could prove a valuable resource for grid services provision such as frequency response and voltage control. Furthermore, their participation in the wholesale power market may also prove a commercially attractive proposition (IRENA, 2019b). However, the active participation of a distributed resource is a cause of concern to the networks from an operational perspective, something that has been discussed by Basso, (2009). All respondents agree to a varying degree on allowing distributed ESSs participate in providing grid services and on wholesale power markets. In this context, the costs and benefits for the grids from allowing distributed ESSs to provide grid services and from participating in wholesale markets need to be carefully assessed; including ESSs in an aggregator role.

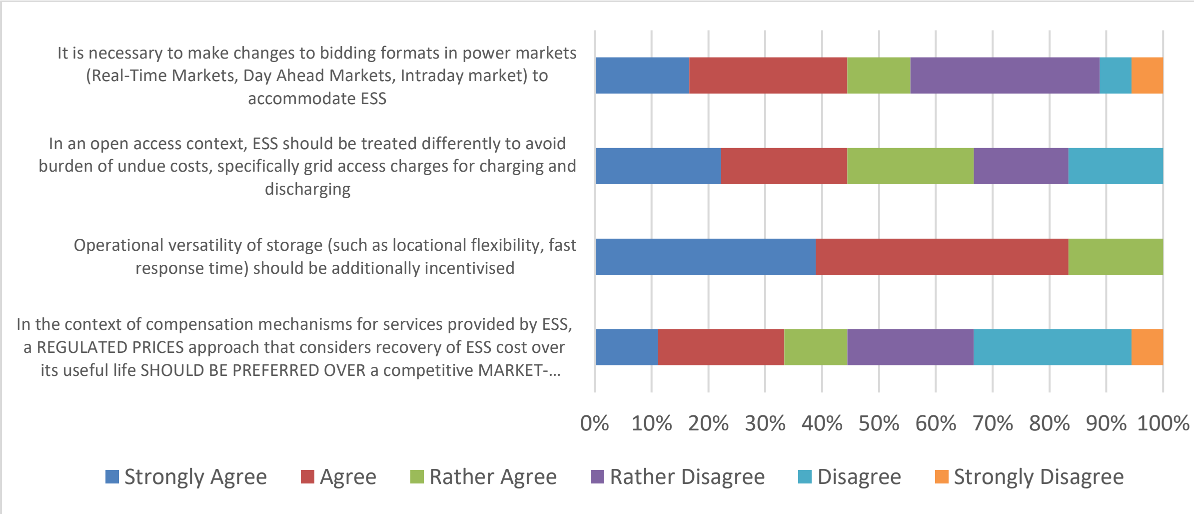
The application of ESSs can potentially allow transmission and distribution companies to defer investment in physical network assets. Network companies would, indeed, require a cost-benefit analysis to find the right mix of wire, ESSs and other innovations. The question that needs to be asked here is the level of regulatory oversight that would be required in the next expansion planning process. Thus, we asked our respondents to tell us to what extent they agreed on the following statement. *"In the context of allowing ESSs to replace wires during grid expansion planning for grid investment deferral, regulators should APPLY A CASE-BY-CASE APPROVAL approach rather than leaving the complete decision on network companies with NO RESTRICTIONS."* Although at an aggregated level, it is observed that more respondents leaned towards a case-by-case approach (61%), the number of respondents leaning towards no restriction was significant (39%). Considering these results, this issue is one that needs further discussion. Indeed, it should be noted that a regulator would consider a "toolbox" of several non-wired solutions together, while designing incentive regulation rather than incentivising ESSs in isolation.

Thus, in the network context, the survey shows that there is: a preference for no restrictions on storage ownership; a need for the development of dedicated grid connection standards; and the need for allowing distributed ESSs in the provision of ancillary service and for participation in wholesale markets. Nevertheless, there is also a need for more discussion on the separation of ESS ownership and operation, and on the level of regulatory oversight on ESS use in grid investment deferral.

5. ESSs in the power market

Based on the literature review, this survey identifies and discusses four market issues that would be relevant for the Indian power sector. These issues are: 1) need for a change to bidding formats in power markets; 2) grid access charge structure for ESSs; 3) need for incentivising the operational versatility of ESSs; and 4) a choice of a compensation mechanism for various services that can be provided by ESSs. The main results are presented in Figure 4.

Figure 4: Responses to survey questions on ESSs in the power markets context



From the power-market perspective, there may be a need to modify the existing market design to eliminate barriers for ESS entry to the wholesale power markets. He et al., (2016) identify this issue in the ancillary market design structure where compensation is based on committed capacity. Thus, the full potential of fast responding storage devices such as batteries cannot be exploited and consequently their revenue from ancillary markets may be underestimated. Different approaches have been employed globally to address this issue such as creating special markets for fast responding resources (UK EFR), modifying existing markets with additional incentive for fast response as in PJM (FERC Order 755) or technology specific procurement such as in California (Bhagwat, 2017). Respondents are divided on the need for changing the bidding formats to accommodate ESSs. At an aggregate level, 55% of respondents agree to a varying degree (16% strongly agree and 27% agree), while 45% disagree.

The reviewed literature shows that to unlock the full potential of ESSs with regards to the services they can provide and to ensure their efficient monetization, it may be necessary to modify existing market dimensions, such as bidding formats, that have been developed for traditional technologies. The survey results on this topic are split and it is evident that in general, more discussion would be necessary on the extent to which bidding formats need to be modified. Indeed, this topic is emergent in the Indian context. Indeed, there is a strong consensus on the need to incentivise the operational versatility of ESSs.

The ability of ESSs to act as generators as well as consumers in the traditional sense may lead to duplication in costs, specifically grid access charges for charging and discharging. These added costs can be a significant entry barrier for ESS systems preventing them from participating in the power market. Respondents lean towards agreeing that ESSs should be treated differently to avoid a possible duplication of costs (see Figure 4).

Two approaches might be considered for remunerating ESSs. The first is the implementation of a regulated price for different services that ESSs provide with the possibility of ensuring financial viability and the risk of inefficiently set prices. A second approach would be to allow the market to set the price competitively depending on the value that is attached to all or to any of the services provided by ESS.

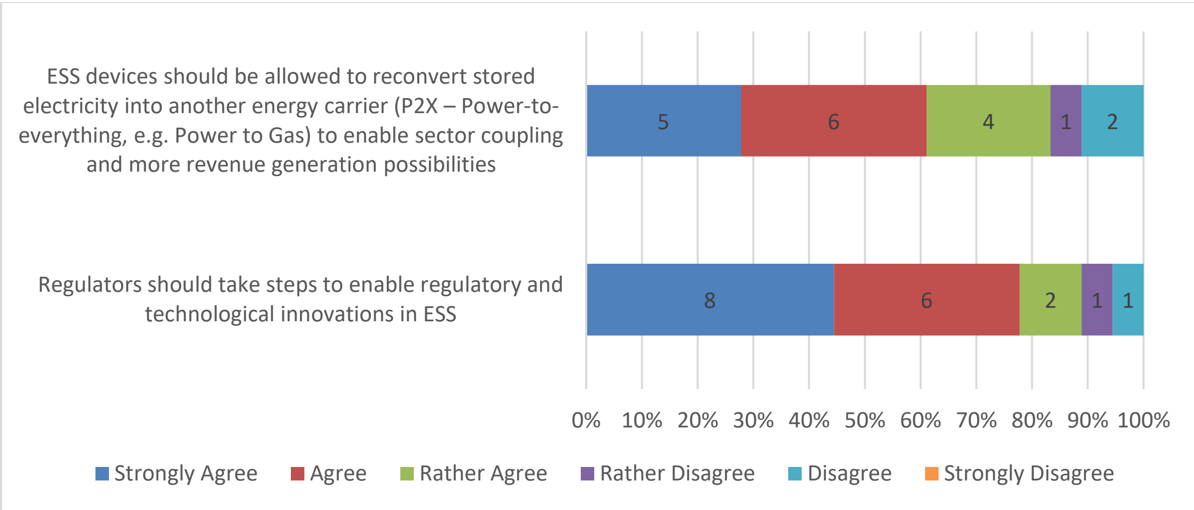
Opinion is split almost equally between regulated pricing versus market-based pricing for ESS services. This topic, indeed, is only just starting to be discussed in an Indian context.

Thus, in the context of markets, it might be observed that there is much less convergence in opinion and that, therefore, there is the scope for further in-depth studies. At an aggregate level, based on the survey, there is a need for updating bidding formats, special treatment of ESSs for grid access charges and for incentivising the operational versatility of ESSs. However, a critical aspect to be discussed in greater depth is the type of compensation mechanism.

6. ESSs in the innovation context

Innovation affects the power sector not only in terms of technology but in terms of the economics of the electricity industry, the business models and regulatory actions. Innovation can occur as both the development of a completely new concept or the improvement of existing concepts. In this survey, with regards to innovation, two key issues have been addressed: 1) enabling innovation in ESS development by regulators; and 2) reconversion of stored electricity into another energy vector. The main results are presented in Figure 5.

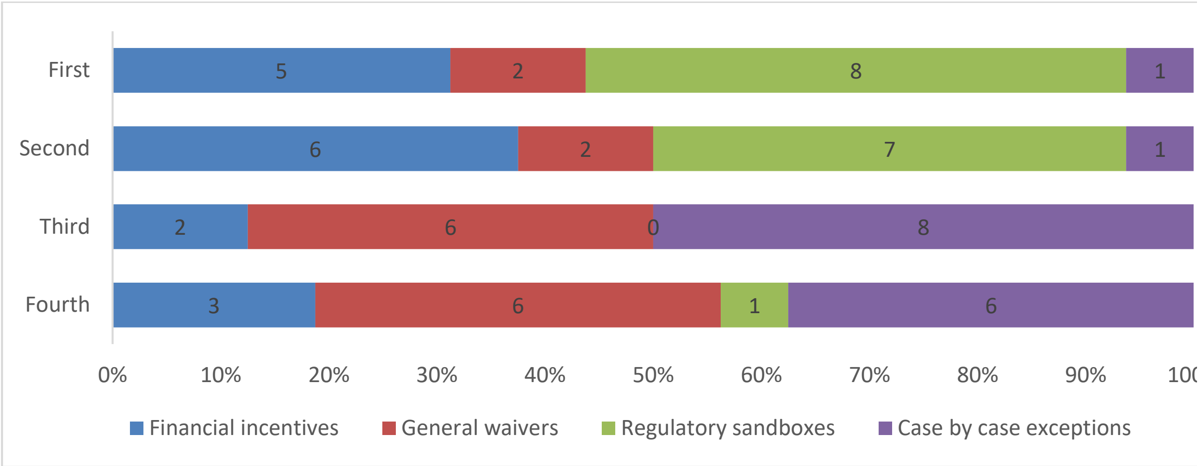
Figure 5: Responses to survey questions on ESSs in the context of innovation



ESSs allows stored electricity to be converted into different power vectors such as hydrogen and other green gases. In this way ESS service providers are given an additional pathway to monetisation. This can provide huge opportunities for the further greening of the economy (Bhagwat and Olczak, 2020). There is an agreement among our experts that ESS devices should be allowed to reconvert stored electricity into another energy carrier (P2X – Power-to-everything, e.g., Power to Gas) so as to enable sector coupling and more revenue generation possibilities.

In order to support the development of ESSs it is important for regulators to support new and innovative technologies. There is also agreement that regulators should take steps to enable regulatory and technological innovations in ESSs. Regulators can use several approaches to enable innovation, see further Schittekatte et al., (2020). The respondents were asked to choose between four possible regulatory approaches for enabling ESS innovation. It was observed that the use of regulatory sandboxes (i.e., a framework set up by a regulator that allows innovators to conduct live tests in a controlled environment) was the preferred option for 50% of the respondents and the second option for 44% of the respondents. Financial incentives were the first choice for 31% and the second choice for 38% of the respondents. (See Figure 6).

Figure 6: Ranking of different tools in order for priority for enabling regulatory and technological innovations in ESS[1]



Thus, the experts favour innovative ideas for enabling ESS. Progressive ideas such as P-to-X conversion and the use of regulatory sandboxes are supported.

7. Conclusions

The following key conclusions can be drawn from the results of this expert survey. The respondents agree that ESSs are needed to run the Indian power system efficiently. Furthermore, there is agreement on the need to develop special regulations for ESSs, which includes a regulatory definition of ESSs. However, further discussion is needed on the approach necessary for developing this definition in the Indian context.

In the network context, there is agreement on no restrictions on the ownership of storage, the need for the development of dedicated grid connection standards and for allowing distributed ESSs to participate in the provision of ancillary service and wholesale markets. However, more discussion is necessary on separating ownership and the operation of ESSs, and on the level of regulatory oversight on the use of ESSs for grid investment deferral.

In the context of markets, it can be usefully observed that there is much less convergence in opinion on different issues and thus scope for further in-depth studies. At an aggregated level there is agreement on the need for updating bidding formats, providing special treatment to ESSs regarding grid access charge and for incentivising the operational versatility of ESSs. However, compensation mechanisms need to be further discussed. Finally, our experts favour innovative ideas for enabling ESSs. Progressive ideas such as P-to-X conversion and the use of regulatory sandboxes are supported.

[1] Note that only 16 participants responded to this question which was optional.

Need for ESS in India

- **Insights**
  - ESS Solutions are necessary for the efficient running of the Indian power sector in the foreseeable future.
  - There is a need to develop dedicated regulation for ESS, which includes a regulatory definition of ESS.

- **Future research topics**
  - Approach to be applied for developing ESS definition in the Indian context.

ESS in the network context

- **Insights**
  - There should be no restriction on ownership of ESS by any entity.
  - Develop dedicated grid connection standards for ESS.
  - Allow distributed ESS to participate in ancillary service provision and wholesale markets.

- **Future research topics**
  - The separation between ownership and operation of ESS.
  - Level of regulatory oversight in the use of ESS for grid investment deferral.

ESS in the power market context

- **Insights**
  - Update of bidding formats to enable ESS participation is needed.
  - ESS must be provided special treatment regarding grid access charge.
  - Operational versatility of ESS must be incentivised.

- **Future research topics**
  - Compensation mechanism to be applied.

1.ESS in the innovation context

- **Insights**
  - Reconversion of electricity to other energy vectors should be allowed.
  - Regulators must encourage innovation and use new approaches such as regulatory sandboxes.

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Appendix I

Reference	Brief description
AEMC 2016	This document discusses the rule change made by the Australian Energy Market Commission in response to a rule change request submitted by the Australian Energy Market Operator. The rule amends the definition of 'generating unit' in the National Electricity Rules (NER) to clarify the rules for eligibility for registration as a generator to be technology-neutral to allow the inclusion of non-traditional generation like battery storage and solar PV.
AEMC 2015	This paper examines whether changes to regulatory frameworks are required to integrate energy storage in the electricity sector in Australia.
Anaya and Pollitt, (2015)	This article discusses the commercial and regulatory issues arising from the integration of energy storage into the power system with a focus on the United Kingdom.
BATSTORM, (2018)	Key topics presented in this report are recent developments and future trends within the battery energy storage market, discussion on the EU's Strategic Energy Technology Plan, role of batteries in the ten-year Roadmap developed in the framework of the Batstorm project.
Bhatnagar et al., (2013)	This report conducted a literature review and a stakeholder in survey in four regions of the United States to identify barriers to energy storage development in the country. The report presents possible solutions for addressing these barriers. It also reviews initiatives around the US at the federal, regional and state levels that are addressing some of the identified issues.
Castagneto-Gissey and Dodds, (2016)	This paper studies regulatory barriers faced by power-to-power energy storage in the UK and in other major international markets. The authors discuss various aspects such as role, regulatory definition, ownership, business models and market design
CERC, (2017)	This is a discussion paper about storage technologies and various issues on the deployment and operations of grid level storage technologies. The paper covers the applications of storage technologies, operational frameworks, tariffs and other related issues.
European Parliament, (2019)	The European Union's directive on common rules for the internal market for electricity includes the definition of energy storage as well as other articles that elaborate on various regulatory dimensions on energy storage such as ownership of storage and market participation.
FERC, (2018)	Order 841 of the Federal Energy Regulatory Commission (FERC) amends the regulations to remove barriers to the participation of electric storage resources in the capacity, energy, and ancillary service markets operated by RTOs and ISOs in the United States
Fitzgerald et al., (2015)	This paper explores four questions in the context of ESSs: 1) grid services that batteries can provide; 2) location of service provision – behind the meter, distribution-level, transmission-level; 3) value from services provided by batteries; and 4) regulatory barriers for storage to provide stacked service to the grid.

IRENA (2020)	This report presents a five-phase method for assessing the value of storage and for creating viable investment conditions. IRENA's Electricity Storage Valuation Framework (ESVF) aims to guide storage deployment for the effective integration of solar and wind power. The report examines the ESVF process for decision makers, regulators and grid operators. Further it explains the ESVF methodology for experts and modellers. Finally, real-world cases are discussed.
IRENA (2019a)	This report provides an overview of grid-scale battery storage and their role in renewable integration in the system. Some examples of grid-scale battery storage deployment and their impact are also discussed.
IRENA (2019b)	This report presents an overview of a market design innovation that allows DERs to provide grid services, through wholesale and ancillary service markets and being exposed to market prices.
IRENA (2017a)	The report presents challenges and solutions for adapting the electricity market design to integrate high shares of RES. The report focuses on wholesale market design as well as distribution networks and DER
IRENA (2017b)	This report provides an overview of markets and cost projects for storage and renewables up to 2030.
Jain et al., (2013)	This report by CEEW discusses the available storage technologies in India and associated challenges while moving towards more efficient technologies. It also presents points of engagements for the Renewable Energy Working Group (REWG) to push for innovations in the policy framework for off-grid renewable energy.
Kuldeep et al., (2016)	This report presents an overview of the Indian energy storage market for off-grid solar. It discusses various energy storage technologies and assesses opportunities from the rapid adoption of off-grid renewable energy. Key challenges for battery manufacturers such as technology costs, and climatic performance uncertainty in India are also presented.
Meeus and Bhagwat, (2018)	This book chapter debates whether ESSs are an asset that only market parties should be allowed to invest in, or whether it can also be considered as a transmission and distribution asset that system operators can invest in as part of their monopoly activity.
NITI Aayog, (2019)	This study presents an ESS Roadmap for India for the period 2019-2032 with the aim of aiding Indian policy makers and utilities in decision making related to investments in ESS. The report also covers policy and tariff design recommendations for ESS.
NREL, (2019)	This document answers various fundamental frequently asked questions regarding grid scale battery storage such as characteristics, location and compensation mechanisms amongst others.
Potau et al., (2018)	This report provides an overview of policies in the UK, Germany, Netherlands, Italy and Spain, applied to support the battery technologies rollout. A list of Dos and Don'ts for national policies and overall supporting the EU environment are also discussed.
RGI and CAISO, (2019)	This report presents the key main trends in energy storage between Europe and California. The key topics covered are the benefits of

	energy storage, types of energy storage, global forecasts, initiatives for incentivising energy storage, technical requirements for ESSs, and barriers for development and deployment.
Ruz and Pollitt, (2016)	This paper compares California and Europe to present avenues for overcoming barriers for ESS development. The main barriers identified by the authors are inadequate definitions and the classification of ESS in legislation; lack of markets for some ancillary services; inadequate market design that benefits traditional technologies; and the lack of need for ESSs in some jurisdictions.
Schittekatte et al., (2020)	This paper presents experiences with regulatory experimentation in the Netherlands, the UK and Italy. Implementations are compared on six points: eligible project promoters; scope of the derogations; length of the derogations; administration of the experiments; funding; and transparency. The authors also discuss the evolution of these approaches and discuss the application of these learnings in enabling experimentation at the European level.
Sioshansi et al., (2012)	This paper surveys technical, non-technical and policy related barriers and proposes some potential research and policy steps for addressing them. The discussion is mainly focused on the United States.
Walawalkar et al., (2007)	This paper assesses the economics of sodium sulphur batteries and flywheel energy storage systems in New York state's electricity market. The assessment indicates a positive economic case for ESSs for applications such as energy arbitrage, and regulation services. Benefits from deferral of system upgrades and charging efficiency are important considerations in the economics of ESSs in a competitive electricity market.
Woodman and Baker, (2008)	This paper discussed various elements of the UK's market and infrastructure regulatory framework which may limit the development of decentralised energy. In this context the paper looks at current conditions, future advances and opportunities.

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