RE-EMPOWERED

Renewable Energy EMPOWERing European & InDian Communities

Deliverable 2.2: Obstacles to Innovation Report

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DEM Demonstrator, pilot, prototype	**CO** Confidential, only for members of the consortium (including the Commission Services)
DEC Websites, patent fillings, videos, etc.	**EU-RES** Classified Information: RESTREINT UE (Commission Decision 2005/444/EC)
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EXECUTIVE SUMMARY

This document contains useful information about the obstacles that RE-EMPOWERED project will face at the demonstration sites and during the development of the tools. Precisely, the report analyzes the impact and differences in energy policies, regulations and directives in India and European Union (EU). Further, it discusses how these frameworks tend to influence various other dimensions at macroeconomic level while imposing corresponding changes in energy sector. Moreover, this information guides towards the identification of specific obstacles to innovation, in the energy value chain, across a broad spectrum, which, in turn, provides direction for exhaustive understanding of the four demonstration sites in India and EU, in the context of microgrid deployment for clean energy access for residential and commercial purposes. Furthermore, the work in this document is extended to drivers with a potential of overcoming obstacles or mitigating risks. This analysis has also been undertaken for the project's toolset (ecoTools) by deploying a multi-criteria decision-making technique.

In conclusion, the findings pertaining to all the analysis, discussions, information has been recaptured from various perspectives with gap identification and plausible existing and future provisions for strategic planning and action. Intense examination, extensive discussions with an attempt to connect relevant dots to highlight the criticality of obstacles in the innovation landscape, considering the project, makes this document suitable to provide some guidelines to the involved actors, partners, stakeholders, innovators, project developers and policymakers.

This document aims to highlight findings after in-depth analytical evaluation of the inherent obstacles and drivers with variable degree of potential impact on the demonstration sites, as well as developed ecoTools solutions of the project. This report reflects the relevant policies, regulatory framework, existing obstacles to innovation as barriers and drivers in the four demonstration sites of India and EU, focusing also on the ecoToolset, which is the innovative technical solution to be deployed in the demonstration sites, for the operation of local energy systems, for clean energy access to the remote/ rural communities in India and the optimal operation of the microgrids existing in the European islands of Kythnos and Bornholm

KEYWORDS:

Energy Policy, Regulations, India, European Union (EU), PESTLE, Obstacles to Innovation, Stakeholders, Community, Microgrids, Barriers, Drivers, Technical, Social, Environmental, Financial, Fuzzy TOPSIS, Demonstration site, SWOT, DEMATEL, ecoToolset

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Acronyms

Acronym	Description
ACER	Agency for the Cooperation of Energy Regulators
AREP	Accelerated Rural Electrification Programme
AT&C	Aggregate Technical and Commercial
BPL	Below Poverty Level
CIM	Common Information Model
DDG	Decentralized Distributed Generation
DDUGJY	Deendayal Upadhayaya Gram Jyoti Yojana
DEMATEL	Decision Making Trial and Evaluation Laboratory
DISCOMs	Distribution Companies
DRE	Decentralized Renewable Energy
DSO	Distribution System Operator
EMD II	Electricity Market Directive II
ESCOs	Energy Service Companies
EU	European Union
EUEP	European Union Energy Policy
FITs	Feed in Tariffs
GEDCOL	Green Energy Development Corporation of Odisha Limited
GHG	Greenhouse Gas
GoI	Government of India
GoWB	Government of West Bengal
GUI	Graphical User Interface
GW	Giga Watt
GWp	Giga Watt peak
HEMRM	Harmonized Electricity Market Role Model
ICT	Information and Communication Technology
IEP	Indian Energy Policy
IMPRINT	Impacting Research Innovation and Technology
INDC	Intended Nationally Determined Contribution
IoT	Internet of Things
IREDA	Indian Renewable Energy Development Agency

KPIs	Key Performance Indicators
kWh	Kilowatt hours
kWp	Kilowatt peak
LCA	Life Cycle Analysis
LSEs	Load Serving Entities
MEZ	Micro Enterprise Zone
MNRE	Ministry of New and Renewable Energy
MW	Mega Watt
NABARD	National Bank for Agriculture and Rural Development
NECP	National Energy and Climate Plan
NGOs	Non-Government Organizations
NIIs	Non-Interconnected Islands
NSM	National Solar Mission
O&M	Operation and Maintenance
OREDA	Odisha Renewable Energy Development Agency
PEC	Power Electronic Converter
PESTLE	Political, Economic, Social, Technological, Legal, Environmental
PIA	Project Implementation System
PMGY	Pradhan Mantri Gramodaya Yojana
PM - KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan
PPC	Partial Power Converter
PPP	Public Private Partnership
PV	Photovoltaic
P2P	Peer to Peer
RAE	Regulatory Authority for Energy
R&D	Research and Development
RD&D	Research, Development and Demonstration
RE	Renewable Energy
RECs	Renewable Energy Credits
RES	Renewable Energy Source
RESPs	Rural Energy Service Providers
RED II	Renewable Energy Directive II

RETs	Renewable Energy Technologies
REST	Rural Electricity Supply Technology
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
ROI	Return Over Investment
RPOs	Renewable Energy Purchase Obligations
RPS	Renewable Portfolio Standards
RTS	Rooftop Scheme
SCADA	Supervisory Control and Data Acquisition
SDGs	Sustainable Development Goals
SECI	Solar Energy Corporation of India
SERC	State Electricity Regulatory Commission
SNAs	State Nodal Agencies
SWOT	Strength, Weakness, Opportunity, Threat
TOPSIS	Technique for Order Performance by Similarity to Ideal Solution
TRL	Technology Readiness Levels
UC	Use Case
UDAY	Ujjwal DISCOM Assurance Yojana
VECs	Village Energy Committees
WBGEDCL	West Bengal Green Energy Development Corporation Limited
WBREDA	West Bengal Renewable Energy Development Agency
WBSEDCL	West Bengal State Electricity Distribution Company Limited
WG	Working Group
WTP	Willingness to Pay

1 Introduction

1.1 Purpose of the document

The Deliverable 2.2 "Obstacles to Innovation" is produced within the Work Package 02 "Foundations and Innovation Analysis" under Task 2.3. It analytically describes the obstacles to innovation and detects barriers and drivers in both the EU and Indian context. It also foresees the coordination on policy relevant issues (e.g. regulatory framework, technical, social and environmental framework) with similar India and EU funded projects through the BRIDGE initiative. The relevant differences between EU and India are captured and analyzed in order to facilitate further collaboration and knowledge exchanges between the EU-India partners. Among others, the BRIDGE initiative's activities will be monitored, and results will be included in the analysis. Its aim is to provide an in-depth innovation landscape in the energy sector, promoting clean energy solutions which are to be developed, deployed, and demonstrated for local energy production and consumption in the RE-EMPOWERED project. Moreover, it provides a framework in the regulatory, technical, social, and environmental perspectives which is imperative for successful deployment of the ecoToolset in islanded microgrids, small energy systems and generate insights for informed decision-making process. Further, RE-EMPOWERED will cooperate with other H2020 Smart grids, Islands and Digitalization projects to exchange experiences, lessons-learned, best practices through the BRIDGE Cooperation group to ensure active exchange of knowledge and experiences, to better understand the needs to be satisfied and the specifications set in the development of RE-EMPOWERED's solutions to achieve sustainability and replicability.

1.2 Structure of the document

This document starts with the purpose of the deliverable document D2.2 of RE-EMPOWERED project, its objectives and the information about the energy status with electricity access and role of involved stakeholders in Indian and EU context. This report provides understanding about the energy policies as well as regulatory framework, highlighting the pertinent issues within the structural background in Indian and EU context. It provides insights by developing analytical policy option matrix through a specified instrument to evaluate the identified major policies based on various criteria. This analysis reports effectiveness of the identified policies providing an environment and regulation for promoting the penetration of renewables in the energy mix. This information illustrates reference and strategic action points. The macro political- economic- social-technological-legal-environment setting is further linked with the issues in the energy market for recognizing the corresponding obstacles to innovation in energy technologies and systems through PESTLE (Political, Social, Social, Technological, Legal, and Environmental) framework.

This extends and visualizes the distribution of various barriers which are significantly impacting the penetration and share of renewables. The range of barriers forms the foundation for a second layer identification of obstacles, which are though generic in nature but correlated further to energy projects in a given landscape without considering differentiation across the country specific context. It characterizes the obstacles at meso level i.e. interactions among different stakeholders at national/ regional and local level vis-à-vis macro level. Fuzzy TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) is used to further analyze these barriers for prioritization and relative importance.

After the quantification of obstacles to innovation for energy market, renewables and projects, next exercise is to understand the four demonstration project sites of RE-EMPOWERED which are selected for the deployment and demonstration of the microgrid involving the innovative ecoToolset developed in the project. Hence, it is imperative to elaborate upon the technical, social and environmental barriers operating at the demo sites and hindering the development as well as deployment of ecoToolset. Not alone the obstacles but also the potential drivers are assessed to overcome some of the existing barriers. SWOT (Strength, Weakness, Opportunity, Threat) analysis is done for the demo sites to mark the strengths, weaknesses, threats and opportunity associated with respect to the project sites for the successful installation, implementation and operation of the microgrid. Moreover, feasibility and viability is tested and validated through this exercise for the proposed development of various ecoToolset. DEMATEL (Decision Making Trial and Evaluation Laboratory) which is a strong analytical technique is used to decipher the inter-linkages among the barriers and drivers to source out the cause and effect relationship. This will act as a guideline for project developers and stakeholders to for pre-planning and organizing the activities ahead of any similar project deployed along with the road map and an appropriate action plan for efficacious replication of such projects to realize the heavy investments made to achieve last mile electrification and decarbonization.

This report presents the documentation of complete analysis of obstacles to innovation using the funneling procedure whereby filtering is done from a broader perspective to narrowing down to the micro level at demo sites and ecoToolset.

2 Energy Status: India and EU

2.1 Energy Status: India

India has set an ambitious target of achieving 40% share of installed power capacity from non-fossil fuel based energy resources by 2030 under 'Intended Nationally Determined Contribution' (INDC) submitted to United Nations Framework Convention on Climate Change [1, 2]. Keeping it in view, government planned to increase installed capacity of renewable power generation to 175 GW by 2021-22 [1]. Data from previous years reveals maximum installation of renewable power generation capacity is grid interactive with only 2.5% off-grid installed capacity [3]. Reasons for such a low installed capacity of off-grid systems are on account of lack of dedicated and favorable government policies, less awareness for decentralized generation and energy efficient products, lack of subsidies, less participation from user side, etc. [4]. To meet the desired penetration of renewable power, off-grid generation needs to be emphasized, as until and unless end user is aware about the utilization of renewable sources of power and shows adaptability to renewable power generation and consumption, it is difficult for the nation to achieve the desired goals [5, 6]. These objectives can be met to a certain extent with one of the evolving and consumer-oriented approach viz. decentralized renewable energy (DRE) model.

2.1.1 Electricity Access in India

Presently about 239 million people in India don't have electricity, most of them reside in poorer rural households. Interestingly, 60% of these reside in villages that already deemed to be electrified, as a village in India is termed as electrified if it possesses basic electricity infrastructure with electricity connection at public places and minimum 10% of the households electrified [7]. Even households having electricity connection lack reliable power supply, experiencing power cuts ranging from 4 hours to 20 hours in a day. Only about 7% of the electrified households in villages report no power outages while 18% report outages up to four hours a day [8]. Poor power reliability curtails electricity benefits to under privileged communities and makes electricity connection more expensive. Still, around 70% of electrified households use kerosene as back up lighting source and spends on an average INR 26 per month on fuel for lighting purpose only. The amount is nearly equivalent to the cost of 10 units of electricity. However, rural access rates are increased by 18% in period 2000-2010, with rural and urban residents accounted for 70% and 30% electricity access gains during 2000-2010 [9]. Section one focuses on the energy policies and schemes for electricity access in India and the other section thoroughly reviews the off-grid solar microgrids in specific context to selected two states – West Bengal and Odisha– under study.

2.1.2 Off-grid Energy System in India

Off-grid/ Decentralized/ Distributed energy system could be defined as small-scale energy generation units, at, or near, the point of use, where the users are the producers, whether individuals, small businesses and/or local communities [9]. These production units could be stand-alone or could be connected to nearby others through a network to share, i.e. to share the energy surplus. In the latter case, they become locally distributed energy networks, which may, in turn, be connected with nearby similar networks. Previous studies report the suitability of off-grid initiatives like Decentralized Renewable Energy (DRE) systems in providing last mile energy access to remote and left over communities where grid extension very often appeared unviable [10]. These systems are locally administered characterized by products like solar lanterns, home lighting systems and small scale microgrids providing energy access to cluster of households. Such systems provide access to clean and reliable energy to off-grid communities and strengthen the local economy. Few of the reported cases of DRE systems demonstrated the socio-economic transformation of beneficiaries; however, critical studies are required in this sector to assess the acceptance and suitability of such systems in off-grid and grid connected households and commercials.

Solar mini/ microgrids aren't new to India. Households and enterprises across rural India have been installing small off-grid solar photovoltaic (PV) battery storage systems rapidly in recent years. India has a natural advantage of its tropical topography to generate solar power. Most parts of country enjoys roughly 300 sunny days in a year. With expected 4-7 kWh solar radiation per square meter, country is projected to generate about 5000 trillion kWh per year by installing solar panels over its unused barren lands. Understanding this potential, Govt. of India has revised its National Solar Mission target of grid connected solar power projects to 100 GW by 2022 from the original projection of 20 GW [11], which includes 40 GW of rooftop solar and 60 GW of medium and large scale grid connected power plants [12]. Aggregating and collectively managing these adds reliability, robustness and resilience to the power supply. It also improves efficiency, enabling end-users to meet their energy needs, while reducing carbon emissions and environmental degradation associated with fossil fuel power generation. Further, National Policy for Renewable Energy based Micro and Mini Grids (2016) was introduced for state subsidies provisions and proposed the exit options with tariff regulation to promote such projects. In continuation, a Mini Grid Renewable Energy Generation and Supply Regulations, 2016 was also notified in 2018 for service standards.

India's high energy demand, import requirement and energy poverty, necessitates high impetus on solar energy. Tariff for solar power has fallen to an exceptional level of below INR 5 per unit from INR 18 per unit as continuous innovations makes solar technology economical thus promoting clean energy [12]. However, numerous challenges still pose threat in achieving this ambitious target. According to Central Electricity Authority, Indian solar power generation suffers nearly 40% transmission and distribution loss. Target is to reduce this loss to 18% by improving the distribution segment through reforms [11]. Moreover, subsidy structure for solar installations facilitation continues to remain complex. Inappropriate policy mechanisms to check meeting of Renewable Power purchase Obligations is the pertinent issue for solar power producers.

Renewable energy based mini-grids and micro-grids offer viable, clean and efficient solutions, however, they have been given residual role in our electricity programs. Based upon availability of land and solar radiation, the potential solar power in country has been assessed to be around 750 GWp. According to National Solar Mission (NSM) annual report 2018-19 [13], the state-wise estimations shows that the solar energy potential is highest among Western and Central part of the country while lowest to moderate in North-east and Eastern region. At this juncture all 29 states and seven union territories are doing some activity related to production of electricity using renewable energy. Thus, the focus on Solar Energy is due to its high potential leading to heavy investments from government and non-government institutions.

2.1.3 Role of Indian Stakeholders

Multiple stakeholders have been associating to spread the technologies on renewable energy globally. The eminent stakeholder of the sector, i.e., government, non-government, private, and international organizations besides users are playing a key role in the dissemination and promotion of technologies on renewable energy. The government is playing the role of a facilitator as well as a regulator in renewable energy programs in both emerging and developed economies. The role of private partners is essential as well, especially entrepreneurs. They are the key to the diffusion of renewable energy technologies through production, marketing, distribution, installation, and servicing. The most important stakeholders among all are the users. The last few decades' experiences revealed that a holistic approach is most fruitful in the diffusion of renewable energy technologies because that ensures absorption of technology over only adoption considering user requirements.

One more stakeholder who plays a key role in the dissemination of information, awareness generation, and technology diffusion is the Non-Government Organizations (NGOs). They play a key role in technology transformation as well as execution at the grass root. Lastly, another stakeholder who has a great role in the diffusion of technology is the international organizations. They often play the role of a donor as well as capacity building facilitator besides an advisor. Mostly they play a bigger role in developing nations, but their innovative approach defines the success of diffusion of technologies because that defines acceptance and ownership of locals towards renewable technology. In conclusion, it may be stated that stakeholders working with a shared vision and common goal increase the chance of renewable energy technology diffusion and absorption besides adoption.

Organization	Classification	Key Roles

State Nodal Agencies (SNAs)	State Level Agency	• Build, operate, manage, monitor micro-grid facilities
		• Identify areas in need of energy projects
		• Generate and distribute electricity
		• Collaborate with ESCO supervisors
		• Replace ESCO management in scenario of non-operational, abandoned, or poorly functioning ESCO
		  ○ Mostly for non-subsidy electricity projects, though applicable to private ESCOs as well
		• Contribute technical and operational support to SERCs settling ESCO disputes
		• Ease exit procedures by providing support throughout process
		  ○ Provide advice and guidelines on procedures
		  ○ Assists with closures
		  ○ Helps prepare and finalize contracts

		• Collaborate with Ministry of Power to generate data for PIA

State Electricity Regulatory Commission (SERC)	State Level Agency	• Create secure payment methods for exit options and oversees exit procedure
		• Set energy tariffs in accordance with National Tariff Policy
		• Help settle ESCO disputes
		• Develop clear and measurable metrics of performance
		  ○ Encourage domestic electricity consumption
		  ○ Promote hybrid solutions to increase reliability of electricity supply
		  ○ Ensure minimum hours of domestic electricity supply

DISCOMs	Energy Provider	• Buy excess micro-grid energy from ESCOs • To avoid over-competition and interference with micro-grid market • Not economically viable in rural or low-income areas
ESCOs	Energy Provider	• Abide by state-specific policy and tariffs • Can charge tariff to local community with their consent (if operating in an open market) • Typically operate in rural areas that cannot access main grid systems (DISCOMs) • Often eligible for state subsidies

Project Implementation System (PIA)	State Level System	• Developed by state's Investment Promotion Board
		• Database registered ESCOs must regularly upload data and metrics of performance to
		  ○ Location of grids
		  ○ ESCO details
		  ○ Quantity of households connected
		• Data is publically available
		• Categorizes micro-grids based on kW size
		  ○ Less than 10kW— Category A
		  ○ 10 kW to 100 kW— Category B
		  ○ 100 kW to 250 kW— Category C
		  ○ 250 kW and above— Category D

Panchayat (Village Council)	Village Level Agency	• Organize Village Energy Committee (VEC) to address community disputes regarding companies • Collaborate with energy providers to set tariffs • Certify No Objection Certificate mandating the community's permission to legally implement new projects • Promote community participation of projects
Village Energy Committees (VECs)	Village Level Agency	• Determine energy tariffs • Recalculate tariffs if surplus energy is sold to DISCOMs

Table 1 Key Stakeholders of State and Local Policy in India [14]

Therefore, it is critical to identify the group of stakeholders in this project as well at four different demonstration sites for the deployment of the RE based technologies and innovation. Local people's participation with local authorities will be of foremost importance for successful implementation and functioning of the isolated microgrid in India.

Several Indian states have taken the lead introducing policies to ensure investing environment for microgrid operators. In India, state governments are responsible for setting official tariffs and creating state-specific energy regulations. State Nodal Agencies (SNAs) collaborate with Energy Service Companies (ESCOs) and the State Electricity Regulatory Commission (SERC) to generate fair tariffs by energy providers, reducing vulnerability to energy monopolization in rural communities. SNAs often connect private energy providers with the communities in which they operate, target high priority areas for electrification and innovate ways for financial investment. SNAs act as intermediaries between ESCOs, Distribution Companies (DISCOMs), and the local villages they service for new electricity projects implementation, energy generation and distribution, and settling local disagreements. SNAs are positively embraced by villagers, ensuring communities respond consensually to the implementation of electrification projects. Additionally, they monitor the success of ESCOs by creating audit procedures and report outlines that ESCOs must regularly submit. Their most distinct feature is assisting failing ESCOs throughout shut-down scenarios or managerial transfer. A contingency fund is available to maintain and continue operation of stranded or failing micro-grids. States have the ability to regulate and intervene in micro-grid projects, while their interventions strengthen the viability of energy projects, but they can also become barrier to production. Contradictory, the heavy role of state regulation competes with that of microgrid companies to offer energy at minimal and cost ineffective rates sacrificing potential revenues in order to service larger proportion of low-income customers [14].

SERCs are largely responsible to design the broad contours of the power sector in the country. They frame regulations for power generators, transmission utilities and the distribution companies in their areas of jurisdiction. Public companies mostly dominate the power sector across the value chain, except in the generation sector where private sector is very active. While central government backed generation companies may supply power to multiple states, generation companies owned by state governments supply power to the parent state only. Post generation, electricity is transmitted through government or private transmission utilities. In addition to the above stakeholders, an important role is played by trading companies and power exchanges to balance the demand and supply of power. A wholesale electricity market ecosystem has been created for easy interaction between generators and large consumers at both national and state level.

At local levels it is the Village Councils and VECs that facilitate for land acquisition, local approvals, manpower provisions, tariff collection, monitors operation and maintenance (O&M), and motivates community engagement, while also enable ownership structure. These local bodies and committees represent the grassroots innovations to address energy poverty and social justice through inclusive community engagement, equity in benefits distribution, empowerment of marginalized communities, and networking towards sustainability.

2.2 Energy Status: EU

As a result of the ever-growing needs and consumption, today EU's energy sector accounts for more than 75% of the EU's greenhouse gas emissions [15]. Back in 2014, the need for decarbonization started becoming even more prominent and this led to the adoption of EU's climate and energy framework (revised in 2018) which targets "at least 40% cuts in greenhouse gas emissions (from 1990 levels), at least 32% share for renewable energy and at least 32,5% improvement in energy efficiency for the period 2021- 2030" [16]. Furthermore, to deliver on the EU's Paris Agreement commitments, in February 2015 the Energy Union strategy (COM/2015/080) was published as a key priority that targets to build an energy union providing EU consumers - households and businesses - with secure, sustainable, competitive, and affordable energy [17]. In November 2016, a new energy rulebook was proposed and was finally adopted in 2018, the so called "Clean energy for all European" package, which is a landmark for the implementation of the energy union strategy. The package consists of eight new laws regarding the Energy performance in buildings, Renewable energy, and Energy efficiency, Governance of the energy union, Electricity regulation, Electricity directive, Risk preparedness, and Agency for the Cooperation of Energy Regulators (ACER) [18]. Finally, in 2019, the "European Green Deal" has provided the EU's long-term strategy of achieving carbon neutrality by 2050. The 3 main pillars of the new strategy for the clean energy transition, are the provision of a secure and affordable EU energy supply, development of a fully integrated, interconnected and digitalized EU energy market and prioritization of energy efficiency, improvement of buildings energy performance and development of a power sector largely-based on renewable sources [15]. The new market mechanisms, business models, technological approaches and regulatory frameworks promote a consumer-supported network and empower citizens to become fully active players in the energy transition.

2.2.1 Electricity Access in EU

Apart from the EU's internal strategies and regulations, EU works with international organizations and partners to combat climate change and promote sustainable development worldwide. In September 2015, at the United Nations General Assembly, countries from all over the world singed up to the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) [19]. Some of the most relevant and important goals are the ending of poverty in all its forms everywhere, ensure availability and sustainable management of water and sanitation for all, ensure access to affordable, reliable, sustainable, and modern energy for all, and take urgent action to combat climate change and its impacts [20]. Based on the Energy Progress Report 2021 [21] which aims to register and assess the global progress on energy access, energy efficiency, renewable energy and international cooperation, the following are some of the main messages to be delivered:

- The share of the world's population with access to electricity grew from 83 percent in 2010 to 90 percent in 2019. Worldwide, 1.1 billion people gained access between 2010 and 2019. With the increasing electrification, the number of people lacking access fell from about 1.2 billion in 2010 to 759 million in 2019 during this period. Continuous progress was made from 2017 to 2019, with 130 million people gaining access to electricity each year, slightly more than the average of 127 million people who gained access each year between 2010 and 2017 [21].

- Even the growth in electrification was significant over the last decade, the current pace isn't sufficient to meet the goals of the SDGs by 2030. To achieve 100% access of electricity globally, the pace growth must be accelerated through the adoption and implementation of appropriate measures tackling the status quo [21].
- Rural areas account 84% of the global population living without access to electricity (640 million people) in 2019, even though the electrification progress in rural areas was faster than in urban, the last decades.
- Although progress in rural areas was faster than in urban settings over the 2017–19 period, rural areas still accounted for 84 percent of the global population living without access to electricity (640 million people) in 2019. For that reason, It is important to address complexities related to affordability, reliability, and the cost of deploying solutions to reach populations living in isolated or informal settlements that consume small quantities of electricity.

2.2.2 Off-grid Energy System in EU

In Europe, most of the off-grid systems are Non-Interconnected Islands. In the Clean Energy for All Europeans Package there is a special reference to the potential of islands to contribute to Europe's energy transition. Acknowledging this potential has led to the launch of a special initiative for EU Islands, the Clean Energy for EU Islands Initiative (CE4EUI Initiative), supporting EU islands in accelerating their transition towards clean energy. The Political Declaration to establish the CE4EUI Initiative was signed on 18 May 2017 by the European Commission and Energy Ministers of 14 EU countries, i.e. Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Malta, Portugal, Spain, and Sweden. The signing of the Declaration during the Maltese Presidency created the necessary political momentum and commitment from almost the majority of MS with islands to the establishment of the Initiative. The Inaugural Forum marked the official launch of the CE4EUI Initiative. In his opening speech, the European Commissioner for Climate Action and Energy Miguel Arias Cañete revealed the Commission's plan to have 1,000 islands decarbonized by 2030, an ambitious target that requires a high degree of organizational, technical, and financial innovation to take place on islands.

The EU Islands Facility is the EU's main instrument to put this policy into practice on more than 2,000 islands representing 14 different countries. The Facility supports island communities in planning, designing, and developing a strategically sound set of projects and attracting the required investments. This will be accomplished by providing islands with technical assistance in the form of small grants and targeted support from local and topical experts. The Facility complements the work started by the CE4EUI Initiative. Launched in October 2019 and with a 4-year duration, the Facility will distribute €6 million in small grants and offer €1 million worth of technical support to islands aiming to fund 60 successful energy transition projects, mobilizing more than €100m of investment and reducing significantly CO_2 and GHG emissions by 2023.

In June 2020, a very significant policy piece reinforcing the support by the EU for the clean energy transition of islands has been signed by 14 Member States (Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Malta, Portugal, Spain, and Sweden) and the

European Commission. The MoU sets as objective to establish a long-term framework for cooperation to advance the energy transition for islands adopting recommendations from EU islands. This cooperation focuses on the promotion of sector integration among energy and transport, water, heating/cooling, as well as the facilitation of renewable energy communities and citizens' energy communities on islands. Finally, the Memorandum of Split recognized the necessary support to islands not connected to the national grid in their decarbonization process through the increased use of renewables in final use of electricity and of transport, heating and cooling.

2.2.3 Role of EU Stakeholders

This section focuses on the stakeholders that are relevant to the EU demo sites in Denmark and Greece. The national frameworks that specify the roles and the responsibilities of the stakeholders are determined by the European Parliament Directives and their adjustment to the national frameworks by the governments.

On top of the list of the relevant stakeholders stands the Regulatory Authority for Energy / The Utility Regulator. Its main role is to monitor the compliance of the energy market stakeholders to the relevant framework and ensure customers protection. As neutral market facilitators, distribution system operators (DSOs) and transmission system operators (TSOs) are responsible for the secure operation of the distribution network and the transmission network respectively. DSOs must ensure stable and continuous power supply to end customers, as well as plan and conduct the necessary reinforcements at the low/medium voltage network. TSOs main goal is to operate, maintain and plan the extensions of a robust network. They must ensure the connection of generation unit to the network in a non-discriminatory way and the constant energy supply to the DSOs. TSOs and DSOs have a high level of interaction. Specifically in Greek non-interconnected islands, DSO also assumes the role of TSO. Directly connected to the energy market are also the energy/gas supply companies. In general supply companies are private enterprises that participate in the energy market and provide continuous energy/gas supply the end customers. The energy supply is achieved through the distribution network.

Except the directly related to the power system, a key stakeholder at the demo site are the local authorities. As the public institutions closest to citizens, local authorities are responsible for executing a mandate in line with their constituencies' needs, mainly through the provision of basic services, ensuring inclusive policymaking and inducing sustainable development. They are able to mobilize all local actors involved in development processes, while acting as catalysts for change [22]. In support of local authorities' activities, the non-government organizations (NGOs) could act and increase local engagement in the energy transition process, provide technological tools/solutions and act as active consultant for both local authorities and citizens. Universities could also support local communities by providing innovative tools and experience, organizing workshops, and run pilot projects that raise the consumers' awareness and improve community's sustainability. Energy Communities (ECs) could also embody that role. It is proven that ECs enable active consumers, a key role for the energy transition. Last, but not least, locals and local businesses can participate in the demo site with multiple roles. For example, at Bornholm demo site local farmers and forest owners provide fuel (slurry, straw, waste and manure) for the production of district heating.

Organization	Key Roles
Regulatory Authority for Energy	• Monitor and surveillance of energy market • Consumer Protection • Monitor DSO & TSO • Regulatory measures for the effective functioning of energy markets • Monitor regulation of the infrastructure of electricity, gas, heating sector
Distribution System Operator (DSO)	• Safe, secure and continuous operation and management of the distribution system • Distribution network planning and development • Ensure access to power for all customers • Collection of metering data • District heating network management (Denmark)
Transmission System Operator (TSO)	• Operate, maintain, plan of extensions of transmission network • Provide access to the electricity market stakeholders (i.e. generating companies, supply companies, DSOs, aggregators)
Energy supplier	• Provide energy to end customers • Provide dynamic billing contracts • Aggregate flexibility
Gas supplier	• Provide gas to end customers
Local authorities	• Basic services to local community • Improvement of local infrastructures • Plans towards sustainable development
University	• Provide tools/experience/material to local community • Organize workshops for citizen engagement and awareness • Organize and participate in pilot projects that benefit local communities
Non-Government Organization (NGO)	• Local authorities consulting • Provide tools/experience/materials to local community • Raise local awareness • Organize and participate in pilot projects that benefit local communities
Energy Community (EC)	• Enable active customers • Benefit local communities • Improve sustainability • Minimize energy poverty in local community

Locals	• Act as active customers and prosumers • Provide fuel for the production of district heating (Denmark)

Table 2 Key Stakeholders of EU

3 Energy Policy Analysis: India and EU

Power sector is responsible for 25% of annual global greenhouse gas emissions, with emissions of about 12 billion tons of CO_2. Emissions are expected to grow to nearly 18.9 billion tons by 2050, comprising roughly 30% of annual greenhouse gas emissions in 2050. Without additional policies, the power sector will be responsible for 28% of cumulative emissions through 2050. The growth in emissions is caused largely by growing amounts of coal and natural gas used for power generation. Reducing power sector emissions is imperative by use of less coal, natural gas, and oil while replacing them with zero-carbon technologies/ resources to produce power and reduce the demand for electricity. Significant reductions in greenhouse gas emissions are necessary to limit climate change and makes decarbonization to reach the 2°C goal more difficult. Evidence causing potential damage from climate change and its intimidating challenge are visible, however renewable technologies and strategies exist to overcome it. Ten energy policies have been identified in past two decades i.e., during the period of 2000 to 2020 which were formulated and implemented in both India and EU, plus land-use emissions reductions, has potential to reach this goal. These policies aim diversified industrial targets by accelerating the transition through carbon free power generation by energy efficiency standards, emissions, renewable portfolio standards (RPS), feed-in-tariffs (FITs), energy security, carbon pricing, along with the complementary power sector policies. These policies are essential for decarbonizing the economy in cost effective manner. Although the effect of carbon pricing is directly related to the price or emission cap used, yet strong carbon pricing set at the social cost of carbon can achieve 26% of the emission reductions necessary by 2050 to hit the two-degree target. Similarly, support for research and development (R&D)/ innovation is critical to lowering the long run costs of decarbonization, and typically targets technological breakthroughs in the economy. R&D coupled with strong policies driving deployment, have helped reduce the costs of zero-carbon electricity generation technologies, including solar photovoltaics and wind turbines. Cost declines coupled with well-designed policy shows how R&D fits together to accelerate the clean energy transition.

3.1 Major Energy Policy/ Regulations in India

India is the third-largest consumer of electricity in the world. Therefore, for India uninterrupted source of electricity production is nonnegotiable. Globally renewable energy generation is experienced from solar, wind, biomass, ocean waves, and geothermal. These energy sources depend on the topography, global positioning, and the sun-earth geometry of a nation. The nation ranked 3rd in the 2021 renewable energy country attractive index. The country aims to achieve 175 GW renewable energy by 2022 and 500 GW subsequently by 2030. Till 2020, the nation installed 38.8 MW solar, 38.7 GW wind, 0.2 GW Biomass, 45.7 GW larger hydro, and so forth so on. India's Central Electricity Authority in the year 2018 promised to produce half of the required electricity from non-fossil by 2030. Based on the fast proliferation of renewable energy sources and technology in Indian energy market with decarbonization of economy, Government of India (GoI) enacted for policy formulation and regulation implementation. Present section highlights few major such Indian Energy Policies (IEPs) in the power sector from a timeline of past two decades spanning from 2000 to 2020.

In 2001, GoI declared a Rural Electricity Supply Technology (REST) mission to electrify India by 2012, thereby significantly increasing engagement within the energy sector. The main objectives of this initiative were to increase energy access and affordability, transition from fossil fuels, and mitigating climate change. Because electrification and development are inextricably linked, India's rural development goals also drive this effort. To accomplish this scale of electrification, the Ministry of Power has assumed a larger role in supporting renewable energy projects while minimizing barriers to entry for businesses through deregulation. Although the Ministry continues to enforce safety and technology standards, it has reduced regulations for private Energy Service Companies (ESCOs) [14].

Code No.	Policy/ Scheme	Date Notified	Description
IEP1	*Electricity Act 2003*	2003	Major focus is on framing of National Electricity Policy and Tariff plans with promotion of renewable energy sources. This act exempts local community, Panchayat Institutions, Cooperative societies, user associations, NGOs and other franchisees to obtain license for electricity distribution in their respective area by recommendation of respective government. It directs regulatory commissions to specify obligations for distribution utilities to procure certain amount of renewable energy out of the total electricity consumption in their respective areas. There was an amendment in the act in 2018 with 24-7 energy supply, initial reduction of cross subsidy by 20%, eventual elimination of cross-subsidies within three years, penalties or removal of license if failure to supply quality power.
IEP2	*National Electricity Policy*	2005	Aimed to provide electricity access to un-electrified rural households with per capita availability of electricity to be increased to over 1000 units by 2012. It stipulates the creation of Rural Electrification Distribution Backbone to provide electricity connections to rural households either by extending centralized grid or by setting up Decentralized Distributed Generation (DDG) systems involving renewable energy production in a cost effective manner. Government facilitates intended beneficiaries by providing capital subsidy and soft long term loans to set up rural electrification projects to provide electricity to rural community at cheaper rates. Special focus is given to promote non-conventional sources of energy in a cost effective way.
IEP3	*Rajiv Gandhi Grameen Vidyutikaran Yogana (RGGVY)*	2005	Aimed to accelerate electrification of rural households with provision of providing free electricity connection to BPL households. Primary focus on installation of Village Electrification Infrastructure either by grid extension or standalone systems. The scheme covered electrification of 97759 villages with intensive electrification of 202865 already electrified villages along with free electricity connections to 16.5 million households till 2015. RGGVY recommended standalone electricity generation systems where grid connectivity is either not reachable or economical.
IEP4	*Remote Village Electrification Programme*	2005	Focus is to provide basic lighting/ electricity requirement to un-electrified villages/ hamlets by utilizing renewable sources of energy. It aimed to cover un-electrified hamlets of electrified villages having population more than 300 people.

IEP5	*National Tariff Policy*	2006	Mandates Regulatory commissions to fix RPOs on energy service providers to promote renewable energy. It directs regulatory commissions to fix minimum share of energy purchased through renewable sources by distribution licensee which is in accordance with the availability of renewable resources in particular region. Under this, mechanism of Renewable Energy certificate (REC) is evolved under which renewable energy based company could sell power to local DISCOMS at the tariff equivalent to conventional power generated tariff and the balance cost would be adjusted by selling REC to obligated entities.
IEP6	*Rural Electrification Policy*	2006	Aimed to electrify all villages either by grid extension or off grid systems with target of providing minimum lifeline consumption of 1 unit per household per day as a merit good by year 2012. Under REP, a village is deemed to be electrified if at least 10% of the total households in village are electrified. Policy provides special dispensation to stand alone system with rating not greater than 1 MW.
IEP7	*Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY)*	2015	Aimed to provide continuous power to rural India with electrification of all census villages by 2018 and connections to all households by 2022. Primary focus is on grid extension with provision of installing decentralized system wherever grid extension is not feasible. Under this scheme financial assistance provided by centre as grant is 60% and remaining 40% of project cost is arranged by DISCOM by loan (30% of project cost) from financial institutions and its own contribution (10%). By June 2017, out of 597,464 census villages, 595,690 villages (99.7%) have been electrified leaving behind 1774 villages to be electrified.
IEP8	*Ujjwal DISCOM Assurance Yojana (UDAY)*	2015	It is aimed to turn around the precarious financial position of state power distribution companies (DISCOMS). The scheme envisages financial turnaround, operational improvement, reduction of cost of power generation, development of RE, and energy efficiency and conservation. The scheme resulted in some positives. Out of the 28 states that implemented UDAY, 10 states have shown either reduced losses or increased profits in 2019. Instead of just focusing on distribution, UDAY focused on interventions in coal, generation and transmission sectors as well.
IEP9	*Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM)*	2019	It is aimed at ensuring energy security for farmers in India, along with honouring India's commitment to increase the share of installed capacity of electric power from non-fossil-fuel sources to 40% by 2030. The scheme is divided in three components: Component A is focused on installation of decentralized grid connected RE power plants by individual farmers and cooperatives. Component B is aimed on installation of 17.50 lakh solar agriculture pumps. Component C is focused on solarisation of existing grid connected agriculture pumps.
IEP10	*Grid Connected Solar Rooftop Scheme (RTS)*	2019	It is aimed to achieve cumulative capacity of 40GW from Rooftop Solar projects by year 2022. The scheme is providing financial assistance for setting up of 4GW of Rooftop Solar in residential sector as well as incentives to DISCOMS to first additional 18GW of capacity addition across the country.

Table 3 Description of Indian Energy Policy

To economically incentivize private investment, the need for policy reform as well as sustainable partnerships is recognized to meet national electrification goals. Further policies like the Pradhan

Mantri Gramodaya Yojana (PMGY) in 2003 promoted electrifying villages by 2012 through decentralized renewable sources and introduced multiyear tariffs with open access. Similarly, Accelerated Rural Electrification Programme (AREP) enacted in 2003 aimed to provide interest subsidy of 4% on loans to extend rural electrification. However, a recent household electrification scheme implemented by GoI like *Saubhagya scheme* addresses grid-based household connectivity which competes and conflicts by exacerbating pressure on microgrids as grid extension may act as a threat to microgrids operation and sustenance.

Multilateral collaborations are facilitated to enhance public-private partnerships with a range of stakeholders for augmenting microgrid sector by jointly designing sustainable energy projects. Government works with institutions in public sector domain like the Solar Energy Corporation of India (SECI), National Bank for Agriculture and Rural Development (NABARD), Indian Renewable Energy Development Agency (IREDA), state government agencies, and local governance (Panchayats). New tariffs effective in 2016 facilitated federal ESCO partnerships, incorporating minigrids as Rural Energy Service Providers (RESPs). This partnership increases private sector investment in microgrid projects through financial incentives and benefits. The Ministry of Power prioritizes empaneling ESCOs in underserved communities while ESCOs operating in all rural regions are eligible to apply for these benefits [14].

3.2 Major Energy Policy/ Regulations in EU

European Union (EU) energy policy is centered on three key objectives: security of supply, sustainability, and competitiveness. Energy infrastructure is top priority of the EU energy policy strategies; electricity transmission, gas and oil pipelines, smart grids, storage of energy and CO_2 transport are essential elements of EU present and future energy systems. Therefore, the EU has adopted the Energy Infrastructure Package for 2020 and beyond. The necessary investments need to happen for this, whereby a stable and harmonized regulatory framework is a must. In an attempt to offer this stability to investors and to facilitate the integration of national markets in the region, EU is establishing cooperation in regional markets for developing new sustainable energy technologies, removal of the current barriers in infrastructure, regulatory environment and investment. Integration of regional markets creates access to cost efficient investments and boost security of energy supply. Furthermore, the establishment of regional groups enhances regional cooperation among EU Member States. Projects of common interests are selected for finding the best value added investments from EU funds with an accelerated permitting procedure reducing the risks of delays.

Code No.	Policy/ Scheme	Date notified	Description
EUEP1	*CHP Directive*	2004	This is directive on the promotion of cogeneration based on a useful heat demand in the internal energy market. It encourages the use of cogeneration in order to promote energy efficiency and energy supply security. The desired condition is expected to be accomplished by establishing a framework for promoting and developing high-efficiency cogeneration. Member States are required to provide reports on the state of CHP in their respective countries, as well as promote CHP and demonstrate what is being done to promote it without obstacles.

EUEP2	*European Union Energy Policy*	2005	It legally includes solidarity in matters of energy supply and changes to the energy policy within the EU. It focuses on three main goals: supply security, sustainability, and competitiveness. It actually defines sustainability as the development of competitive renewable energy sources (RES) and all other carriers of low-carbon energy by reducing energy consumption and concentrating on comprehensive efforts on stopping climate change and improving local air quality.
EUEP3	*European Ecodesign Directive*	2009	It establishes a framework to set mandatory ecological requirements for energy-using and energy-related products sold in all 27 member states. It shows a novel way to incorporate environmental concerns into product design and work towards reducing environmental effects across the product's life cycle through better performance besides affordability. It's an important tool in augmenting Circular Economy strategies in production and consumption systems.
EUEP4	*Energy Efficiency Directive*	2012	This directive mandates energy efficiency improvements within the EU. It was introduced in December 2012. It considers multiple measurements, namely, legal compulsions to institutionalize energy saving schemes, public sectors setting anecdotes, energy assessments, metering, consumer behaviour, funds for energy efficiency, etc.
EUEP5	*Energy Union Strategy (COM/2015/080)*	2015	The Energy Union Strategy is made up of five closely interrelated dimensions, designed to bring energy security, sustainability, and competitiveness in a cost-effective way. It's a framework strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy. The main objective is to ensure - secure, sustainable, competitive, and affordable energy.
EUEP6	*Clean Energy for All Europeans*	2016	It consists of eight legislative acts and brings considerable benefits from the end-user (consumers and prosumers) perspective, the environmental and economic perspectives. The package attains the continuous, uncoordinated inception of the capacity process in EU member states.
EUEP7	*Clean Energy for EU Islands Initiative*	2017	It provides a long-term framework to help EU's more than 2200 inhabited islands generate their own sustainable, low-cost energy. It was introduced in May 2017 to provide a longstanding framework to quicken the shift towards clean energy.
EUEP8	*Renewable Energy Directive II (REDII)*	2018	RED II defines Renewable Energy Communities (RECs) as a legal autonomous entity allowing open and voluntary participation of members in ownership and control of renewable energy projects located in the proximity of members. The revised directive moves the legal framework to 2030, sets a new binding EU target for renewable energy by 2030, and includes the possibility of an upward revision by 2023.
EUEP9	*Electricity Market Directive II (EMDII)*	2019	EMD II defines Citizen Energy Communities have no limitation on the geographic location of controlling members as in the case of RECs. As per the directives, member countries had to take at least minimum measures within a stipulated time frame to liberalize their national markets.

EUEP10	*EU Strategy on Energy System Integration*	2020	It will pave the way towards a fully decarbonized, more efficient, and interconnected energy sector. Sector integration means linking the various energy carriers - electricity, heat, cold, gas, solid, and liquid fuels - with each other and with the end-use sectors, such as buildings, transport, or industry. The integration of the sectors will facilitate the optimization and modernization of the entire EU energy system.

Table 4 Description of EU Energy Policy

Early EU policies targeted the reduction of energy consumption growth or the improvement of energy intensity. The Energy Performance of Buildings Directive and the Ecodesign Directive, target the 'technical' efficiency through energy performance standards in buildings by improving technical equipment and increasing building insulation and energy related end-use equipment. Focus was on changing the consumers' purchasing behavior towards more efficient equipment via mandatory energy labelling scheme for appliances and later with the energy performance certificate for buildings. Another action in EU Energy Policy (EUEP) to change end user's behavior is regular information on real energy consumption, based on metered heating consumption bill than on estimated consumption. Recent emphasis is on Energy Efficiency Directive, with the implementation of smart meters and smart billing, end users' feedback and match energy bills with real consumption. This reinforced the need of targeted and effective consumer information prompting consumer behavior change. Likewise, the EU R&D financial programme H2020 introduced several calls and supported many projects to understand consumer behavior dynamics from an economic, social, and psychological outlook.

EU commission and its research departments are important actors for microgrid development. Further, some communities themselves have been active in initiating microgrid projects. Utilities are involved in community microgrid development in the EU with varying approaches. There are examples of utilities which are proactive in one market, but resistant in another. Many European countries have a history with several renewable energy incentives such as feed-in tariffs, net metering schemes, green certificates and energy origin guarantees. In addition, numerous microgrid development projects have been run within EU research frameworks. However, regulations and legislation still favor traditional structures and change processes are considered slow. Recently, a carbon neutrality ambitious climate target for 2050 is proposed but the current set of policies can't reach the goal of Paris Agreement to stabilize temperature increase below 2°C. EU energy efficiency and energy conservation policies must focus on inducing behavior change in relation to energy consumption. "Clean energy for all" package includes the renewable energy directive of EU commission which requires removal of all regulatory and administrative barriers to the development of community microgrid energy projects and to regularly assess progress focusing on consumer or prosumer. Microgrids are more complex than only distributed resources, implying that a number of regulations and legislation needs to be redefined to remove barriers for community microgrids in Europe. Critical to this development is whether the community is viewed as a utility and regulated accordingly, or if they are exempt from the general utility regulation.

National and regional policies on the energy transition and decarbonization of the islands stem mainly from the National Energy and Climate Plan (NECP), which promotes a radical transformation of the country's electricity sector, as renewable energy should reach over 60% of final electricity consumption by 2030. The plan envisages the promotion of electro-mobility with the recent Law 4643/2019 establishing the regulatory structure for its further development. Specifically, for the islands the NECP in accordance with the ten-year development plan of the Greek TSO foresee the interconnection of most isolated islands with the mainland grid. Grids in Non-Interconnected Islands (NIIs) have been judged to be congested by the Regulatory Authority for Energy (RAE Decision 2016/616), which has set specific limits on the maximum available power for the installation of such units. On the contrary, measures to enhance the installation and permitting of RES stations and the adoption of solutions that combine RES and storage in NIIs are also foreseen by the NECP. For example, Law 4495/2017 contains provisions for Specific Pilot Projects in NIIs.

3.3 Policy Option Analysis and Insights

Policy Options Analysis is a structured way to invent, evaluate, and choose alternative courses of action. It involves predictions of outcomes due to different actions and recommending actions leading to the best outcomes. Policy analysis is to inform and support policy choices, it also requires attention to a community's values, goals, and interests, all of which cannot be derived through a strictly objective process. Result will be a policy outcome matrix that shows the projected outcomes for different policy solutions. It introduces a comprehensive classic approach which represents the overall goal. A complete policy options analysis may include: exploration; review of existing knowledge; or program assessment. It is one framework in which project takes on a broader significance. The criteria is selected against which the projected outcomes for each of the alternative solutions constructed is tested. The identified criteria has been identified from the review process whereby the policies are assessed and evaluated from the performance metrics like effectiveness, regulatory standards, political acceptability, implementation, efficiency, cost, externalities, sustainability and equity. Targeted questions are designed in the form of an instrument to record the responses of the experts to derive policy analysis option scores and matrix.

Criteria	Target Questions
Effectiveness	How effective is the policy in reducing emissions and de-carbonization?
	How stringent are they to achieve necessary climate change goals?
	Does the policy stimulate the market for renewable generation?
Regulatory Standards	How the policy regulate replacement of fossil fuel with zero carbon resources?
	Does the technology efficiency standards reducing fossil fuel consumption?
Political Acceptability	Does the policy designed to maximize their beneficial interactions to accelerate power sector transformation and ensure compliance?
	How the power-sector and cross-sector policy play a complementary role in de-carbonization of economy?

Implementation	How long does policy take to create compensation mechanism for renewable energy generation and expediting deployment?
	How long does policy take to motivate growth across all technologies and minimize developer risks?
	How long does policy take to set fixed procurement targets for load-setting entities of their generation from a defined eligible renewable sources?
Efficiency	Is the policy efficient?
	How well public and private resources are utilized?
	What is the balance between the policy's aggregate costs and benefits?
Cost	Is the policy implementation leading to affordable and cost effective energy solutions?
	Does low-cost options accelerate renewable clean energy transition?
	How does the policy support R&D targeting technological breakthrough for lowering long-run costs of de-carbonization?
Externalities	What will be the second order effects of implementing the policy?
	How will it influence the operation of other govt. programs?
	To what degree will it distort markets for competing or complementary products?
Sustainability	Does policy impact sustainability from economic, social and environment perspective?
	How does it impact?
Equity	Does the benefits and costs of policy be shared out fairly among stakeholders'?
	Does the policy considers inclusion of all the secluded segments of people?

Table 5 Target Questions for Energy Policy Analysis

The 7 point Likert scale is utilized to record more informed and profound insights for more accurate computation of the scores. Respondents are the domain experts with significant working experience who can be policy makers and implementers, renewable energy industry experts, energy innovators, academicians with significant experience in energy research, energy consultants, local authorities, other experts working in energy domain like investors, VCs, incubators, corporates, legal experts. Here, responses from 10 such experts have been collected from both the country i.e., India and EU via mail and further discussion over virtual conferencing/ telecommunication as required. The range of the scale is from minimum 1 (very low/ too short/ very poor/ very negative) to maximum 7 (very high/ too long/ very good/ very positive). Mean score computation is done for each of the policy and based on the value, final sentiment is obtained from a range within minima and maxima for each of the stated level of scale. Estimation highlights that for level 1 the minimum value is 1.00 while maximum value is 1.85 (similarly for level 2 – minima is 1.90 while maxima is 2.70; level 3 - minima is 2.80 while maxima is 3.55; level 4 - minima is 3.60 while maxima is 4.40; level 5 - minima is 4.50 while maxima is 5.25; level 6 - minima is 5.30 while maxima is 6.10 and level 7 - minima is 6.20 while maxima is 7.00).

Based on the analysis the Heat maps have been derived to better understand the overall policy option evaluation which clearly depicts that on which criteria the policies have performed well and what are the strategic areas to further strengthen the impact and achievement of the set goals in energy sector. Heat map for Indian energy policy analysis option matrix demonstrates that the majority of the identified policies have an under-rated performance for the criteria.

Criteria		Mean Score								
	IEP1	IEP2	IEP3	IEP4	IEP5	IEP6	IEP7	IEP8	IEP9	IEP10
Effectiveness	4.4	4.2	3.8	4.0	4.0	3.6	4.4	3.6	3.6	4.4
	4.8	5.0	3.2	4.8	4.0	6.0	4.0	5.0	3.0	4.0
	5.6	6.0	4.0	4.2	5.2	5.0	4.0	3.2	5.0	3.0
Regulatory Standards	3.4	3.2	5.0	4.4	3.6	4.2	4.2	4.0	4.2	3.4
	3.8	2.0	4.4	5.0	4.0	5.0	4.0	3.2	3.0	4.0
Political Acceptability	4.4	2.6	3.6	5.0	4.8	5.0	6.0	5.6	3.0	4.0
	4.2	4.0	5.8	3.8	3.4	3.4	3.4	5.0	4.2	4.4
Implementation	4.4	4.2	4.6	5.0	2.4	5.0	4.4	5.4	5.0	6.0
	3.8	3.6	4.6	3.0	3.8	4.8	6.0	2.8	3.8	5.0
	2.8	3.6	6.0	5.0	3.4	4.0	4.0	4.0	5.2	4.4
Efficiency	5.2	6.0	5.2	5.4	5.2	5.0	3.4	5.8	6.0	4.0
	5.0	5.0	6.4	2.0	5.2	5.2	6.0	3.4	2.8	3.0
	4.0	4.0	4.4	4.6	4.4	5.6	4.4	5.0	4.0	4.2
Cost	3.8	4.0	3.6	4.4	5.0	4.0	4.8	3.0	3.0	4.0
	5.4	4.6	4.4	4.8	7.0	3.4	6.0	4.8	3.8	5.0
	4.8	5.0	3.0	5.4	4.0	4.4	3.6	6.0	5.2	4.8
Externalities	3.0	2.8	5.6	5.6	3.0	2.8	4.0	4.6	5.6	4.0
	2.8	3.0	3.0	3.6	6.6	5.4	2.0	3.0	4.4	2.0
	4.2	4.2	4.0	4.0	2.8	4.8	4.4	3.0	2.8	3.8
Sustainability	3.6	3.6	4.0	2.6	5.0	4.0	4.2	3.2	4.4	3.2
	2.6	2.8	4.4	4.4	4.0	2.0	3.2	2.0	2.4	4.6
Equity	2.0	3.6	4.6	2.4	3.6	3.8	4.8	4.6	3.6	3.4
	2.2	3.0	4.8	4.2	2.6	5.6	5.2	4.8	4.2	2.4

Table 6 Heat Map for Indian Energy Policy Analysis

Green coding with its gradient are the ones performing 'high' followed by the 'medium' represented by the yellow color and its gradient and finally the 'lowest' having color coding ranging between orange to red. On observation, overall IEP6, IEP8, IEP3, IEP5 are the best performing policies followed by IEP7, IEP4, and IEP9 medium while IEP1, IEP2 and IEP10 are worst performers. Majority of the policies scored high on two criteria parameters of efficiency followed by cost justifying the purpose as well as intent, on the contrary sustainability, externalities and equity emerges to be of critical concerns while among others are regulatory standards. Hence, the policy implementation process needs to be more aligned towards providing robustness. Government agencies and policymakers need to chart clear resource outlining which energy policies can put India on the path to a low-carbon future, and how to best design those policies. Further, this clearly calls for a systematic planning for diversified stakeholders' engagement operating non-optimally currently. Sustainability being the most crucial criteria to be achieved is questioned by ineffective implementation and desired impact creation for the majority of the Indian energy policy. Non-aligned regulatory standards further bring complexities for building systematic channel for innovation in renewable technologies under intense competitive environ. This further weakens the scope of commercialization of such technologies which in turn deters the investment from private players and pose concerns for public funding and subsidies.

Heat map for EU energy policy analysis option matrix demonstrates that highest performing policies are EUEP10, EUEP1, EUEP5, EUEP7, EUEP2 closely followed by EUEP9 while others have manifested medium to worse scenario. However, overall performance remains much satisfactory in most of the criteria with top most being equity, efficiency, sustainability followed by parameters on externalities and political acceptability while areas of concern being regulatory standards, implementation along with cost. This explains for the well placed policies across EU in trickling the benefits to all due to strong political will and right interventions.

Criteria	Mean Score									
	EUEP 1	EUEP 2	EUEP 3	EUEP 4	EUEP 5	EUEP 6	EUEP 7	EUEP 8	EUEP 9	EUEP10
Effectiveness	4.4	4.6	3.2	4.0	4.4	3.8	4.4	3.2	4.8	5.0
	4.6	4.4	3.2	4.2	5.6	3.6	4.0	3.0	4.2	3.6
	4.0	5.2	3.8	4.6	4.0	3.4	4.2	3.8	4.0	3.6
Regulatory Standards	3.6	3.8	4.6	5.0	3.4	3.8	4.8	4.0	5.0	5.2
	2.8	4.2	4.4	3.2	4.8	4.6	2.2	3.4	5.0	3.4
Political Acceptability	5.0	4.6	4.8	4.0	5.0	5.0	5.2	3.8	4.0	5.6
	3.8	5.8	3.8	3.8	3.6	4.2	4.4	4.2	4.4	5.2
Implementation	3.8	4.6	3.8	3.2	2.6	3.6	3.2	4.6	5.0	5.2
	5.2	4.8	3.8	4.0	5.0	3.0	3.4	3.6	4.8	4.4
	5.0	5.6	4.0	4.0	4.4	3.8	4.2	4.4	4.4	4.6
Efficiency	5.6	5.0	6.0	3.8	4.8	3.8	5.8	4.0	4.6	4.4
	5.4	4.6	4.8	4.4	4.8	4.8	5.2	4.2	4.8	3.8
	5.2	3.8	3.8	3.4	5.4	3.8	5.0	5.4	3.6	5.6
Cost	5.0	4.2	2.8	4.4	4.8	4.4	4.0	3.8	4.6	5.2
	3.4	3.4	3.8	5.2	4.2	5.2	3.4	5.2	3.2	6.4

	3.8	4.2	4.6	3.2	5.0	4.0	4.8	3.6	4.8	5.2
Externalities	3.6	4.0	5.0	4.6	4.8	5.4	5.4	5.2	4.4	4.4
	4.6	4.8	4.6	6.0	5.2	4.2	4.2	3.8	4.8	4.2
	3.6	3.6	3.2	3.6	4.0	5.0	2.4	3.2	4.0	5.4
Sustainability	4.6	4.8	4.8	4.4	5.2	4.4	4.0	4.6	3.2	5.6
	4.8	3.6	5.0	4.6	4.0	4.0	5.8	4.6	4.8	5.8
Equity	5.4	5.4	4.6	5.2	5.6	3.2	5.0	4.6	3.8	6.0
	6.0	5.0	5.0	5.6	3.6	5.8	5.4	3.8	4.4	4.2

Table 7Heat Map for EU Energy Policy Analysis

There seems to be a contrast in both Indian and EU energy policy high performance metrics whereby expressing more or less commonality with respect to issues. Energy markets in EU are relatively more matured than emerging renewable market in India, therefore they tend to be more focused on achieving the equal level for energy players, cohesive integration with other govt. departments for better planning and execution. The practices in EU pivoted and were oriented towards achieving faster sustainable development goals earlier due to the stages of development and industrialization.

Long term certainty is a central element while applying policy design principles compensating for renewable generators providing investors to receive reasonable return over investment. Aligning guaranteed payback periods with the projected lifetime of the generation technology allows long-term risk reduction for the off-taker. Wind and solar plants typically have lifetimes of 20 years, so compliance of power purchase agreements with RPS requires fixed prices formulation of per unit energy for 10 - 20 years. Likewise, FITs should provide a consistent payment for each technology. Each measure lowers the financing risk, reducing the cost of capital and risk of default or poor performance. Using an appropriate price finding mechanism with elimination of unwarranted soft costs supports the siting, transmission access and transaction cost. In mature energy markets like EU, the load serving entities (LSEs) tend to 'find' the price of renewable energy credits (RECs) in two ways viz. reverse auctions and spot markets.

Moreover, the policies discussed in previous section can be contrasted with capacity targets on one hand and investment incentives on the other. Investment incentives on a capacity basis can be effective stimulants for clean energy investors. However, investment incentives may not guarantee or even incentivize system performance along the lines of developer projections. For example, although investors may receive an incentive to build a wind farm, the off-taker may still bear the risk of maintenance issues, under-generation or over-generation, and inaccurate wind forecasting. Country with immature renewable energy markets may benefit more from policies which minimizes developer risks and stimulates growth of all renewable technologies while as the market matures, allowing the lowest-cost technology to meet a country's renewable energy goals deems appropriate. Each policy can be tweaked to compensate for its perceived weaknesses and can be used successfully together.

3.4 PESTLE Framework and Generic Obstacles to Innovation

The current approach by the Government of India (GoI) in decarbonizing its energy supply is characterized by centralized mega-grids and large-scale solar and wind projects. However, this approach does not create a solution for achieving universal electrification. India's electricity needs are decentralized, so they need decentralized energy solutions. An alternative approach to achieve both universal electrification and decarbonization would include several self-sustaining electricity projects which can be used if there are ever power shortages. Such an approach would improve reliability and accessibility to all India, especially the country's rural poor rural areas. India has installed solar microgrids providing around 2 MW of electricity so far while the earlier plan of constructing microgrids to provide 500MW worth of power by 2022 was shelved. Large private investments are flowing in too, such as the partnership between Tata Power and Rockefeller Foundation to set up 10,000 microgrids by 2026. This project is expected to support 100,000 rural enterprises, create 10,000 new green jobs and provide irrigation for over 400,000 local farmers.

Despite this, many barriers to electrification still remain. Only 9 out of 28 states have reached more than 90% electrification, meaning India is still very far away from meeting its goal of "Power for All" by 2012 as established in its 2001 REST mission. While the cost of implementing renewable energy technology has fallen dramatically in recent years – enough to make it competitive with the fossil fuel industry—the renewable energy sector is emerging, relatively unexplored, and generally perceived as highly risky. Further complicating issue is the plethora of different business models employed by different renewable companies. To navigate diverse energy needs, these companies have become highly tailored and location specific to better serve their own, niche clienteles. Consequently, this makes it difficult to compare impact and success across microgrid companies, which can discourage investors who are unable to adequately project future cash flows and the true potential behind each individual opportunity. Coupling this, many electricity companies face high Aggregate Technical and Commercial (AT&C) losses and uncertain returns on investment in rural areas. Often, this is because of poor management practices, off-grid ineligibility to cross-subsidy benefits, and flawed economic models that have difficulty matching energy supply to demand. As for policy-specific limitations, many argue that the government's enthusiasm to electrify India has been counterproductive in some regards. Because they have created many programs oriented around increasing electricity, less funding has been allocated to each one and there is a need for quality over quantity in their efforts.

In this section, the external factors have been discussed leading to the emergence of context/ project specific corresponding factors creating potential obstacles or barriers in energy sector. Therefore, the approach is generic to identify and map the sources in addition to the energy sector specific barriers operating on its own as well as created as secondary effect. For this, the obstacles are studied in-depth using the framework with respect to the barriers determined by the PESTLE aspects. PESTLE analysis is an audit of six external influences on the decisions and strategy. By analyzing the six factors, researchers can gain insight into the impact assessment, to assess any risks specific to the sector and use that knowledge to inform the policy maker decisions. It considers impact of external forces on a range of plans/ policies for change. It can also highlight the potential for additional costs. A PESTLE analysis can be a powerful activity for understanding the context for change, and the potential areas of focus to make change successful. In this situation, PESTLE is most effective when used in association with a SWOT analysis. PESTLE analysis can be used to monitor the macro-environmental or external factors that play a role in impacting on that environment.

Political analysis looks at the extent and impacts of state power on the economy. Economic factors encompass direct impacts on economic capacity, for an organization, industry sector/ market, or nation. Social factors examine the social context of these institutions including population analytics, demographics and cultural trends. Technological factors are related to technological advancement, including R&D, niche technologies and automation. Legal factors take into account laws and policies, including consumer protection laws, safety standards, and labor laws. Critical environmental factors are conditioned by environmental issues, geographical location, climate changes etc. PESTLE analysis is used to expose issues and discourse qualitatively, particularly, to analyze and break down various problems more holistically. PESTLE analysis has recently been applied to conventional, fossil-fuel as well as renewable energy industries. By using PESTLE analysis, new strategic policies can be developed to replace and renew policies that are no longer effective or efficient. PESTLE analysis undertaken suggests that the development and utilization of renewable energy faces multifaceted barriers from different contexts and aspects.

	External/ policy related factors	Corresponding factors affected by external/ policy related factors	Corresponding factors causing obstacles to innovation in energy sector
Political	Political instability Tax Industry regulations Global trade agreements/ restrictions Institutional issues	Lack of adequate government policies	Conservative risk-averse corporate culture in mature energy sector
	Tax	Conflict between central and state government	Administrative and bureaucratic complexities
	Industry regulations	Overlapping of schemes between Centre and State	Lack of energy policies and schemes aimed to focused research and innovation in energy sector
	Global trade agreements/ restrictions institutional issues	Lack of cooperation among agencies	Lack of standards and certifications for renewable energy products and technology
		Limited private sector participation	Lack of coherence among generation, transmission and distribution sector
		Innovation landscape	Discrimination against big power companies, incumbents and early stage R&D start-ups

		Subsidies	Lack of proper institutional framework for getting open market licenses and registering new energy products
Economic	Import	Indigenous manufacturing technology	Lack of investments in private energy enterprises
	Exchange rates	Local infrastructure and capacity building	Very high switching costs (loss aversion) from switching old technology to new technology
	Globalization	Upfront cost and increased equipment cost	Insufficient allocation of funds for renewable energy development and innovation
	Economic growth/ decline	Supply of RE equipments	Significant technology development costs
	Inflation	Longer payback period	Lack of seed funding for energy start-ups/ incubators
	Interest rates	Low investments and accelerated depreciation	Higher import of expensive technological equipment especially RE products
	Cost of living	More market players	Lack of subsidies and tax benefits for small scale energy innovators
	Labor costs	International pricing	Micro-financing and lending
		Increased competition	
		Private and Public investments	
		Market uncertainties	
		Tariff determination	
		Operation and maintenance planning	

Social	Quality of Life	Energy demand and usage	Lower rate of social acceptance for new energy products
	Empowerment	Energy generation and supply	Public reluctance to utilize renewable energy technologies
	Inclusion	Consumption level	Lack of community awareness towards clean energy
	Consumer asset creation	Community awareness to technology	Community non-involvement from planning to ownership
	Lifestyle factors	Community reluctance to new technology	Unwillingness to pay
	Population demographics	Power quality	Perceived technology performance uncertainty and risk
	Social networking	Capacity building	Social safety net
	Migration	Installation planning	
		Rehabilitation controversies	
Technological	Automation	Installation process	Lack of Indigenous manufacturing technology for in-house development of energy appliances
	Innovation	Manpower requirement	Lack of proper technology transfer mechanism from laboratory to industry for innovative energy products
	Disruptive technologies	Ease of deployment and use	Lack of trained people for understanding and utilizing new technology pertaining to RE sources
	Upgradation	Efficiency and reliability	Lack of infrastructural framework and state of the art laboratories for designing innovative energy products
	Artificial Intelligence	Mass production	Lack of fabrication facilities for electronic devices

	Security	Low manufacturing cost	Higher technology complexity in renewable energy integration
	Block chain	Focused research and development	Lack of data and privacy protection mechanisms
	IoT	Commercial activities	
		High quality and enhanced performance	
		Technology complexity	
		Better management of assets	
		Less human interference with high precision	
		Power theft	
		Grid stability	
		Cyber security and Data privacy	
Legal/ Regulatory	Employment law	Lack of appropriate sectoral and cross-sector policies	Complex regulatory framework for registering new energy efficient products
	Local labor law	Minimum wages and occupancy of regional labor	Lack of regulatory framework for prosumers in smart grid environment
	Safety regulations	Ensuring safe working conditions	Tedious legal procedures for licensing new technology and patents
	Tendering processes	Risk of unethical practices	Lack of co-integration among policies and allied sectors
			Complex national and international tendering processes for vendor selection

Environmental	Environmental restrictions imposed by country govt.	Renewable energy consumption	Lack of mandate for clean energy consumption in commercial sector
	Sustainable resources	Procurement of green energy certificates	Lack of reliable data for forecasting and effective utilization of natural resources
	Procurement, transportation and supply chain management	Transportation of equipments and machinery	Inconsistency for green energy procurement in different industries
	Natural Resource Depletion	Clean energy and Climate change	
		Utilization of solar, biomass, and hydro resources	
		Transportation Cost	
		Procurement of fuel, RE equipments	
		Material acquisition	
		Maintaining fuel supply	
		Power transmission and distribution	
		CO_2 and GHG emissions	

Table 8 PESTLE Framework

Some of these barriers are core to the implementation of energy policy and legal framework while others are arising as a cause-effect outcome. A better understanding of the interconnectedness of these ostensibly different aspects are juxtaposed and highlighted. The analysis illustrates some of the salient features extracted in view of the identified obstacles to innovation specific to energy sector on a larger scale and perspective.

- ***Energy law:*** Intends for energy management; optimal management and availability of energy resources, integration; efficient utilization of energy; ensuring public access to energy; improving industry capacity and domestic energy services; and environmental sustainability. Other laws and regulations related to specific sectors complement foreign investment. The increasing dependence on imported fuels has burdened the financial sector further. An increase of renewable energy can reduce price fluctuations, as well as spur the diversification of energy sources and stabilize the trade balance.

- ***Economic prospect of renewable energy projects:*** They are able to generate returns adjusted to risk yet energy subsidies act as obstacles to fulfill renewable energy targets. Partnership for market readiness to support mitigation activities are formulated for attaining new equilibrium. Reductions in energy subsidies are allocated to price externalities for energy consumption viz. carbon dioxide emissions. Therefore, carbon prices from energy production and energy price usage can potentially make renewable energy sources more competitive and increase their absorption.
- ***Access to financing:*** Investment realization will not happen due to insufficient profit from renewable energy projects and lack of capital. Financing with fair levels of interest, access to financial services, and consistent risks tolerance, underlies investments. It's a specific challenge, where many financial institutions are unwilling to invest in what is perceived as new and risky technologies.
- ***Political economic environment:*** Investors in renewable energy projects must possess confidence for policies that facilitate strong economic prospects for projects as well as access to financing. Volatile price changes has made current policy frameworks less transparent, sustainable and consistent. This has caused investors to be uncertain about investments. A larger framework also needs to be supportive of private investors.
- ***Economic feasibility*** of renewable energy technologies is essential to promote fiscal sustainability and price ranges by comparing generation prices from renewable energy technologies vis-à-vis conventional technologies. Consequently, ignoring renewable energy opportunities from the energy supply side. Pricing strategy fulfils rational targets for internal rates of return and payback period of efficiently operating generators. Financial models supporting price estimations can evaluate existing assumptions for the stakeholders.
- ***Green jobs*** help decrease energy consumption, raw materials, catalyze decarbonization process of the economy, protect and improve the ecosystem and biodiversity and minimize the production of waste and pollution. International Labour Organization declared that a green job characterizes to be adequate, productive, and contains the opportunity to receive ample wages, social protection and social security for workers and their families, as well as the right to conduct social dialogue. National labor conditions promotes underlying factors. Many green jobs are associated to the installation and assembly of renewable energy power plants which are labor intensive and bear short term costs like training, skilling, etc.
- ***Technologies:*** Renewable energy sector requires reliable and cost effective technologies. For this, the network of government and business actors with support from financial sector need to build capital intensive high risk infrastructures for renewable energy. Technology developers and manufacturers express the lack of incentives towards sustainable energy solutions. Despite, uncompetitive value in comparison to fossil fuel energy, prevailing technical constraints causes extended and uncertain period of profit for developers and innovators. Moreover, emergence of automation and smart technologies induces the integration, optimization, flexibility, energy use pattern, data logging, etc. to further diminish demand and supply side barriers. However, this also makes the technology in use to become complex on account of lack of indigenous components manufacturing, lack of proper mechanism for technology transfer, scarcity of state-of-the-art infrastructure and design laboratories, and skilled manpower.
- ***Emissions:*** Several renewable energy options can reduce emissions with relatively low costs and contribute to the improvement and advancement of environmental and human health. Greenhouse

gas emissions and various particles discharged from fossil fuel combustion have negative impacts on human and environmental health. Poor air quality as specified by World Health organization has surpassed the limit across many countries.

- ***Supply chain management:*** Renewable energy development also encompass supply chain capacity impacts which translates into hypothesising the flows of renewable energy and resource/ material into modular yet robust upstream-to-downstream planning. As electronic devices play an important role in the development of innovations, chip shortage is causing shortage in microcontroller boards, various electronic components, and communication devices, which may delay or provide obstacles. Such a supply chain management serves to take into account the various stakeholders involved in the entire sector and accommodate social and ethical issues as well.
- ***Social effects:*** Advancement towards low carbon economy requires inclusion of all stakeholders in a sustainable manner. Creation of safety nets for vulnerable communities with utilization of social capital generated form cohesive and resilient society helps reduce socio-economic barriers for adoption of innovation in energy sector.

Basic purpose is to increase efficiency of the energy sector through market competition. Numerous policy measures aims at restructuring the energy sector, introducing competition and removing other controls. Specific policies intends in creating separate entities for generation and distribution, allowing private sector entry and diluting/ removing controls on energy pricing, fuel use, fuel import, and capacity expansion etc. Institutional measures such as setting up independent regulatory bodies may be needed for success of these policy actions. Pertinent issue is the lack of an overarching law or regulation dedicated for all subsidiary regulations on renewable energy. PESTLE analysis undertaken suggests a need of framework whereby development and utilization of renewable energy requires comprehensive assessment from the aspect of stakeholders and the ability of policy makers to identify the discussed obstacles having risks with a mitigation plan for the same. In addition, through PESTLE analysis, it is possible to better highlight the intersecting and overlapping sectoral interests within the energy sector as a whole.

3.5 Fuzzy TOPSIS for Prioritization of Generic Obstacles to Innovation

Generic barriers have been extracted from numerous project reports, energy literature, policy analysis and PESTLE framework (section 3.3 and 3.4). It is revealed that there are 35 generic obstacles to innovation that exhibits and manifest antagonistic impact on either development of energy innovation or in adoption/ implementation of such novel technologies as local solutions in general. These have been analyzed and prioritized by using fuzzy TOPSIS method.

Although conventional quantification methods present exact solutions, they are not useful to resolve people-centered problems due to the complexities arising from human factors [58]. Therefore, the concepts of fuzzy set theory commonly used in these types of real-world problems where there is uncertainty and fuzziness related with the environment. In real world applications, decision making problems need to be carried out under uncertainty because goals, constraints and possible actions are ambiguous.

The TOPSIS method is a multi-criteria decision making method which uses the distance of alternative from positive and negative ideal solution in decision making. The alternative with smallest distance from the positive ideal solution and largest distance from negative ideal solution is considered as the best solution alternative. If the problem is solved in fuzzy environment, then the method is called as Fuzzy TOPSIS. In this method, the experts provide their responses using the linguistic variable and based on that the numerical operations are performed. Experts have rated the set of alternatives against the specified criteria in the form of linguistic variables ranging from Very Low (VL) to Very High (VH). This technique is applied on the identified barriers based on the preferences/ opinion of experts. The criteria selected for rating alternatives i.e. generic obstacles to innovation are Cost to remove the barrier (C1), Level of effort required to create awareness about the obstacle (C2), and Level of political/ bureaucratic effort required to remove the obstacle (C3). The respective weightages considered for C1, C2 and C3 were 0.45, 0.25 and 0.30.

Inputs are gathered from eight partnering institutions in the project with responses from multiple experts with diversified background having significant work experience in energy policy formulation or implementation; deployment of energy projects; energy service companies; and academic institutions. Experts are selected for this study by taking into account the participation of private, public, and for profit entities directly involved in the development and deployment of the microgrid for providing local energy solutions with demonstration of innovative tools and technologies. The experts' domain attempts to cover the maximum possible stakeholders in the energy local system.

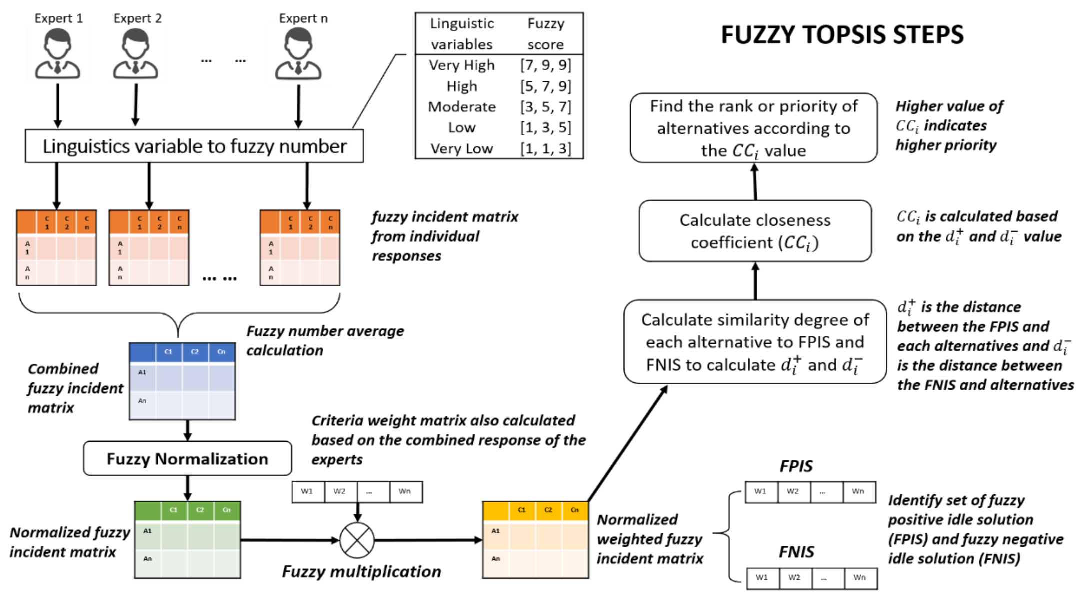

Figure 1 Fuzzy TOPSIS Methodology

There is a range of technical, policy level, social/ community level, financial barriers which pose potential risk towards embracing renewable energy penetration and energy market creation. These exhaustive enlisted obstacles are active and influential across the entire range of renewable energy solutions in different country context however, with some degree of variation. The identified obstacles are ranked from first to seventeenth with a mean value of 0.3614. Overall the ‘Lack of diversity’ is top ranked obstacle while ‘Perceived technology performance uncertainty and risk’ has lowest rank among given obstacles. The ranking scores of top ten obstacles is higher vis-à-vis the mean score which projects that these are the most crucial barriers operating in any energy market derived through Fuzzy-TOPSIS. It includes - ‘Lack of diversity’, ‘Misconceptions regarding reliability of renewable innovation’, ‘Technology usage disconnecting community’, ‘Lack of community awareness towards clean energy’, ‘Setting roadmap and planning without community participation’, ‘Increased cost of the project (required for permits, contracts, community relations and negotiations)’, ‘Digital exclusion of energy communities’, ‘Government dilemma’, ‘Asset longevity’, and ‘Lack of robust technology leading to disparate and disjointed tool sets’. O1 to O4 illustrates dominance of community risks for adoption of renewable energy innovation/ technology which are fundamental for successful deployment and demonstration of any community energy project. It also manifests that despite high value creation and awareness still the predicament among communities could not be resolved effectively by various engaged stakeholders. Further, from O5 to O22, the ranking reveals that more of socio-technical issues pose risks. Conflicting interactions among social fabric and innovative technical solutions are not appropriately mapped and positioned for realization of immediate benefits rather long term welfares which in turn inhibits the sustainability of the microgrids as a whole.

No.	Generic Obstacles to Innovation	Ranking Score	Rank
O1	Lack of diversity	0.8667	1
O2	Misconceptions regarding reliability of renewable innovation	0.8050	2
O3	Technology usage disconnecting community	0.8050	2
O4	Lack of community awareness towards clean energy	0.7181	3
O5	Setting roadmap and planning without community participation	0.3977	4
O6	Increased cost of the project (required for permits, contracts, community relations and negotiations)	0.3977	5
O7	Digital exclusion of energy communities	0.3666	6
O8	Government dilemma	0.3666	6
O9	Asset longevity	0.3666	6
O10	Lack of robust technology leading to disparate and disjointed toolsets	0.3659	7
O11	Lack of accentuation on modern innovation, critical thinking, configuration and experimentation	0.3499	8
O12	Mind-set barriers – grass-root movements, culture shift	0.3499	8
O13	Poor comprehension of community needs and business sector elements	0.3499	8
O14	Lower rate of social acceptance for new energy products	0.3499	8
O15	Weaknesses in IPR administration	0.3499	8
O16	Lack of collaboration	0.3499	8
O17	Technological capabilities providing basic functionality rather competitive advantage	0.3493	9

O18	Security and privacy concerns	0.3493	9
O19	Performance inefficiencies and access speed	0.3104	10
O20	Missing innovation strategy	0.3104	10
O21	Equity structure of assets and ownership structure	0.3104	10
O22	High investment	0.3104	10
O23	Technical debt (technology implemented for short-term benefit)	0.3098	11
O24	Technical complexity and management	0.3098	11
O25	Selecting appropriate location for sitting project	0.3020	12
O26	Lack of seed funding for energy start-ups and incubators	0.3020	12
O27	Societal and civic innovation lags technological innovation	0.2978	13
O28	Transmission infrastructure and power lines	0.2903	14
O29	Unequal play field for renewables	0.2760	15
O30	Skill deficiencies and talent gap	0.2444	16
O31	Underqualified workforce and manpower	0.2444	16
O32	Conservative risk-averse corporate culture in mature energy sector	0.2444	16
O33	Incorrectly measuring and benchmarking innovation	0.1106	17
O34	Missing connections with community while innovating new toolsets	0.1106	17
O35	Perceived technology performance uncertainty and risk	0.1106	17

Table 9 Fuzzy TOPSIS for Prioritization of Generic Obstacles to Innovation

Analysis provide clear indication of the barriers which are operating at micro, meso and macro level of the economy. Majority of the top ranking obstacles are related at the micro level which are the inherent issues within the community or networking glitches with other agents in the society at meso level i.e. interaction with other public/ private stakeholders'. There is also presence of some technical barriers arising firstly due to non-alignment of focus and goals of users and the technology developers, secondly due to lack of an ecosystem for acceleration in awareness and adoption of innovations and lastly due to certain innate social as well as cultural factors which tends to inhibit diffusion of such technologies for daily transactions.

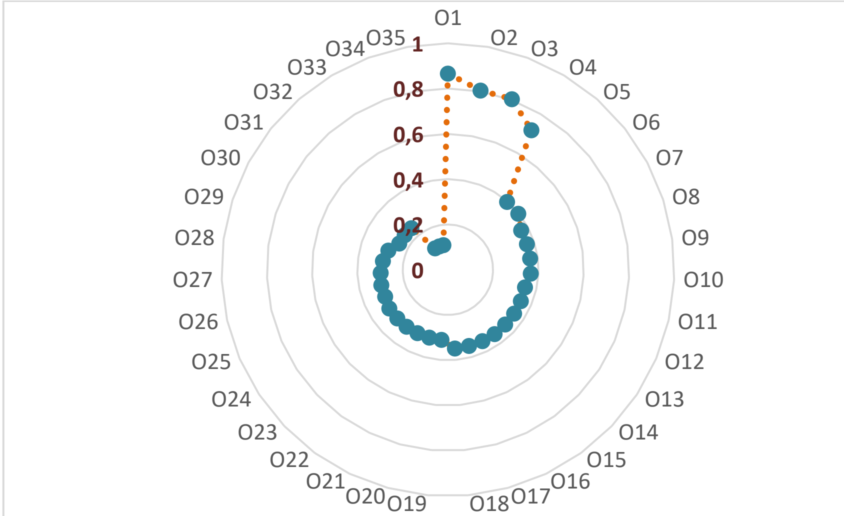

Figure 2 Radar Chart for Obstacles to Innovation from Fuzzy TOPSIS

At the third or the macro level is the govt. dilemma, lack of appropriate dedicated policies, missing co-integration for bringing agreement into diversity. There is a set of 16 obstacles ranging from rank score in between 0.35 to 0.30. Majority of these mid-level obstacles are dominated by creativity, experimentation, behavioral aspects, need of community and social acceptance, collaboration and IP issues followed by technical functionalities, security concerns, inefficiencies, innovation strategy, equity and ownership structure, technical complexity and debt, high investment and seed funding. Next level issues are more from innovation and IP subjects, technical aspects and cost perspective. Finally, the remaining obstacles have score less than 0.30 depicting infrastructure requirements, skilled manpower, corporate culture etc. Such barriers are more of operational related which may be addressed at an individual or corporate level by pivoting strategies, providing training component and alleviating awareness, knowledge sharing and transfer through national and international knowledge partners.

There are primary, secondary and tertiary set of barriers which may be balanced by some drivers while others may not be addressed and therefore there is a need to develop a guideline for the innovators, project developers, private players, beneficiaries, regulators and policy makers to apportion the efforts in which direction and to what extent to eliminate the internal as well as external barriers.

4 Demonstration Sites in India

Two local energy systems will be used for deployment and demonstration of the project's solutions in India, one is Ghoramara Island in West Bengal and other is Keonjhar in Odisha. Electricity profile of both the states is discussed below to understand the potential of renewables and solutions at the identified demo sites. The two demo sites have been selected considering diversity including isolated villages in rural areas of Ghoramara and Keonjhar. Integrated local energy systems can be used to create economically attractive conditions to boost local energy sources and activate local demand-response building a low-carbon, climate resilient future.

Policy Brief: West Bengal, India

West Bengal (WB), one of the most populous states, consumes 4.38% of total energy consumed across India. As per the state utility West Bengal State Electricity Distribution Company Limited (WBSEDCL), there is transmission availability of 99.9%. The demand is mostly met by State's own sources which contribute to more than 64% of total capacity installed in the State. Altogether, 16069.8 mega-watt (MW) electricity in WB is produced by various institutions. Out of 16069.8 MW generated electricity, 10.5 MW gets generated from Small IIP/CCP, and 29 MW from WBSEDCL. In both the cases electricity gets generated from Solar Energy. Setting large power plant is a constraint due to limited arid land. As a result, going by rule of thumb, 1 MW of solar power generating projects were established in 4-5 acres of land [23]. Government of West Bengal (GoWB) initiated their journey towards renewable energy with establishment of West Bengal Renewable Energy Development Agency (WBREDA) followed by creating a separate institute, West Bengal Green Energy Development Corporation Limited (WBGEDCL), in Public Private Partnership (PPP) mode for promoting renewable energy [24, 25]. The main objective was to ensure investment of private sector in renewable energy [26, 27]. First Renewable Energy Policy was notified by the State in 2012. The policy aimed to attain generation of 2,706 MW capacity from renewable energy sources including co-generation by the year 2022 [28]. But now, as per the revised Energy Policy 2016, GoWB was notified a target of 5336 MW by 2022 for solar power generation through grid connected projects and through roof top in the state. The target was notified through Centre as per the perspective plan of action of Centre. Later Centre revised the target to 4500 MW solar energy by 2022 [29]. However, in 2018, GoWB took the decision to achieve own target as per the state's feasibility and practicability. WBSEDCL procured renewable energy from other sources to fulfill its Renewable Energy Purchase Obligations (RPOs) as mandated in 'Cogeneration and Generation of Electricity from Renewable Sources of Energy Regulations' notified in 2013. Till July 2018, WB had installed 80 MW of solar power and it was expected that within a year the state would have ramped it to 200 MW with utmost importance to participation of private stakeholders [27].

Policy Brief: Odisha, India

One of the front runners of Renewable energy installation, Odisha installed 474 MW on-grid solar power plants solar and 0.244 million biogas in 2021-22. The state has aimed to produce 1500 MW by 2022. Odisha has a per capita electricity consumption of 1563.6 kWh compared to the per capita consumption of India, i.e., 1181 kWh in 2018-19. Green Energy Development Corporation of Odisha Limited (GEDCOL) and Odisha Renewable Energy Development Agency (OREDA) are well-recognized organizations that have promoted and installed renewable energy in the state. The state is also aiming to sell electricity at INR. 2.71 per unit which will be extremely competitive for 96.4 lakhs households under Odisha Government. The state is considering the above steps to reduce the emission of more than 30 tons of carbon dioxide per year. One of the front runners of Renewable energy installation, Odisha installed 474 MW on-grid solar power plants solar and 2.44 lakh biogas in 2021-22. The state has aimed to produce 1500 MW by 2022. Odisha has a per capita electricity consumption of 1563.6 kWh compared to the per capita consumption of India, i.e., 1181 kWh in 2018-19. Further, Odisha is also eying to achieve 50 MW of wind energy. The state is considering above steps to reduce the emission of more than 30 tons of CO_2 per year.

4.1 Ghoramara Island: West Bengal

Ghoramara Island is located 92 km south of Kolkata, in the Sundarban Delta complex of the Bay of Bengal. The island is roughly 5 km^2 in area and as of 2016 has 3000 inhabitants. The residents live in very poor conditions while the island is affected by severe cyclonic storms every 5-10 years which leave the people in distress due to snapping off electricity (roof-top PV panels) and unavailability of other livelihood items. This fact makes it very difficult to restore normality after any such situations.

The project aims for development of a local microgrid system to cater electricity in Ghoramara Island, to create sustainable energy community for the island and to improve quality of life for the people residing in the island.

Existing Infrastructure

Regarding the electrical infrastructure, the area is isolated from the utility grid and the residents mostly use Kerosene lamps, while in some houses roof-top PV panel-based electricity is available, but these are far unable to cover the demand. The people residing in this island are very poor and their source of income mainly comes from fishing. The island is away from the mainland and people mostly use paddle-boats as a mode of transportation. This consumes more time but also requires significant physical effort. Since the area is inside the sea, the available wind speed may be utilized to generate electricity that may make the local electricity generation more reliable as PV and Wind may complement each other.

Renewable penetration and citizen engagement

Utility grid is not reached to the area, so an isolated dc/ac microgrid based on renewable energy sources is considered to cater electricity to the island. Moreover, a solar based water desalination plant will be installed. Solar power driven electric boats will be used for waterway communication and electric four wheelers will be considered for ground communication. However, integration of renewable generators is quite challenging because the area is prone to cyclonic storms. Cyclone resilient structures will be developed for PV and wind technologies to enable the successful integration of RES. Building the energy island will be accompanied by community involvement and familiarization with various state-of-the-art tools. Tools and solutions to be demonstrated in this pilot are:

- ecoEMS: Load and RES forecasting will be incorporated within the supervisory control. A web-based GUI will be integrated with smart meter to exchange data between users and microgrid system
- ecoMicrogrid: This tool will be integrated with supervisory control to dictate the required actions like load scheduling, RES power curtailment according to the desired optimization goals
- ecoDR: Smart meters linked with mobile based Android apps will be used for GUI based payment gateway system. It will also help to get data from the users for load control (critical and non-critical load) and dynamic pricing
- ecoMonitor: This solution will be installed at different locations across the Island to continuously measure water and air quality parameters and display it for visual feedback so that necessary corrective actions will be taken accordingly
- ecoCommunity: Using this mobile app-based tool, the residents will be able to monitor their energy consumption data, get update regarding dynamic tariff, switching-off non-critical loads as and when required, pay electricity bills online, etc.
- ecoResilience: PV panels will be mounted on a cyclone resilient mechanical structure so that damage would not occur during high cyclonic storms
- ecoConverter: Power electronic converters and their control methodology will be used to develop microgrid at pilot site, for PV integration
- ecoVehicle: Electric four-wheeler and electric boat will be developed with indigenous electric motor and associated control system to provide easy mobility for transportation purposes and is a critical energy carrier to exploit for synergy

An isolated dc/ac microgrid will be built to cater electricity to each of the houses of this island. Layout of the electrical network which comprises a central dc-grid surrounded by ac grids. At the initial stage, it is estimated that around 300 houses will be given electricity and the similar model may be utilized for future upgradation to cater electricity to rest of the houses. Both single-phase and three-phase options will be provided to the end-users. There would be a total of four ac microgrids each of which provides power to ¼th of the houses, which is approximately 75 houses. Two PV-arrays each of 50kWp will be installed for power generation. A small wind turbine (total 10 kWp) will also be installed to generate electricity. Both PV-array and wind-turbine will be connected to the dc-grid through Power Electronic Converters (PEC) with appropriate power ratings. Various control algorithms will be incorporated within the converter control for reliable and efficient operation of the microgrid. Partial Power Converters (PPC) will be used for PV integration with dc grid to improve power capture during partial shading.

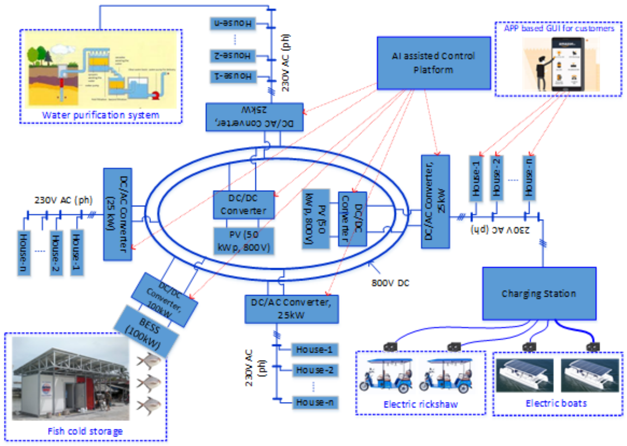

Figure 3 Ghoramara Island, West Bengal: Indian Demo site

Smart meters will be deployed in few houses and other important locations so that data from customer-end can be communicated to the control centre for better coordination between generation and consumption. The smart metering technique will be coordinated with protection technique for reliable operation of the grid. App based GUI enabled payment gateway system will be established which not only serves customers to pay bills, but also allow them to choose various options related to dynamic pricing. Electric four wheelers and electric boats will be developed with indigenous electric motor and associated control system to provide easy mobility on and around the island. A PV based charging station will be installed at some convenient locations within the island from where both electric boat and electric four wheeler can charge their own storage systems. Both conventional and fast charging options will be provided complying various system requirements and standards.

4.2 Keonjhar: Odisha

Kanheigola, Nola and Ranipada are small Villages/hamlets in Harichadanpur-Tehsil reserve forest in Keonjhar District of Odisha State, India. They are located 54 km towards South from District headquarters Keonjhar and 180 km from state capital Bhubaneswar. At present these villages are not connected to the main utility grid. The proposed site is ideal as a test bed and demonstration site as it already has some basic renewable energy facilities. These will be upgraded and coupled with various available energy vectors to improve the living standards of the community. A total of 77 kWp (Kanheigola 30 kWp, Nola 25kWp and Ranipada 22 kWp). Solar PV installations are supplying approximately 1000 villagers, living in 306 households. Every house is provided with 100W that allows basic facilities, like two tube lights and a fan. These solar PV installations are completely isolated. These solar PV installations are completely isolated and commissioned by the Odisha Renewable Energy Development Agency (OREDA) in 2017-18.

The project aims to develop and demonstrate various energy production vectors integration via high energy efficient converters and their control, promote off-grid systems in selected remote villages to create support ecosystems to promote income-generating energy uses in agriculture and small businesses and increase of population awareness and customer engagement, such that rural to urban migration is minimized in Keonjhar.

Existing Infrastructure

No.	Village/ Block/ District	Nature of microgrid: Grid connected/ Isolated	Kind of source in each microgrid	Plant capacity in kW	Load in kW	AC/ DC system	No. of household connected
1	Kanheigola, Keonjhar	Isolated	Solar	30	21	AC system	126
2	Nola, Keonjhar	Isolated	Solar	25	17.5	AC system	105
3	Ranipad, Keonjhar	Isolated	Solar	22	15.4	AC system	75

Table 10 Existing Infrastructure at Keonjhar, Odisha, India

Since all the villages are part of reserve forest, solid biomass from the forest trees can be converted into energy. The optimized and efficient operation of the various energy vectors is highly recommended in order to reduce the high cost, to better manage the energy demand and finally increase livelihood activities of the villagers. In this demo site various energy vectors such as solar PV, biomass, storage, e-mobility and water purification will be integrated with the existing PV system. The main challenge is to design power converters with high efficiency at low power range. The field test is anticipated to demonstrate optimized use of renewable PV solar and biomass power by means of stiff DC-link control capability in standalone mode. The demonstrated solutions, tools, strategies, business models in Keonjhar will enable the development of a socio-economically sustainable model which can be easily replicated in other remote villages in India.

Renewable penetration and citizen engagement

All the three villages in Keonjhar are isolated from the main grid and in the view of financial viability to connect these villages to the main grid is very difficult. The proposed 40 kWp microgrid system as shown in figure will be primarily used for livelihood activities apart from household supply. This will give an ample opportunity to have higher penetration of the renewable energy sources in these remote places. The development in technology and efficient power converter system at low power levels, optimizing the various available energy vectors will increase renewable penetration to greater extent. The proposed microgrid will control various energy vectors, metering, billing and differential tariffs for business, livelihood activities, and household. It schedules demands of microenterprises, irrigation pumps, street lights, etc. The anchor loads are scheduled to match the solar generation profile. A village micro enterprise zone (MEZ) will be created to develop micro-industries for livelihood activities like irrigation through “Field-Distributed-Pumps” and mobile pumps, small enterprises such as agro processing, electric four wheelers, ice factories, cold storage, workshops, water purification stations, telecom towers, petrol stations, commercial banks and community services like schools, govt. buildings. Tools and solutions to be demonstrated in this pilot are:

- ecoEMS: This tool will be used to optimize and manage various available energy vectors available in the Keonjhar pilot case (e.g optimal utilization of the available PV, BioMass resource and battery storage)
- ecoMicrogrid: The controllers developed as part of this tool will be deployed in the Keonjhar pilot site for efficient operation of the available energy vectors
- ecoPlanning: The software developed as part of the tool will be used for studying the planning operations of new renewable energy sources integration of the microgrid in Keonjhar
- ecoDR: The hardware developed (e.g. Smart meter) will be deployed in every household in Keonjhar for pricing purposes and further studies on demand response techniques
- ecoMonitor: Keonjhar Pilot location is close to the mining area sensors will be placed to monitor the water quality and air quality
- ecoCommunity: The digital platform developed will be used for community engagement and consumer energy consumption updating (e.g. Pricing, usage etc.). Workshops and training to local communities
- ecoResilience: The Keonjhar pilot location is a cyclone prone area, the design of structures developed as part of this project will be implemented in this pilot case
- ecoConverter: Modular plug and play converters developed as part of this tool will be deployed for Keonjhar pilot case
- ecoVehicle: The solar powered four-wheeler developed as part of this tool will be used for rural transportation in Keonjhar

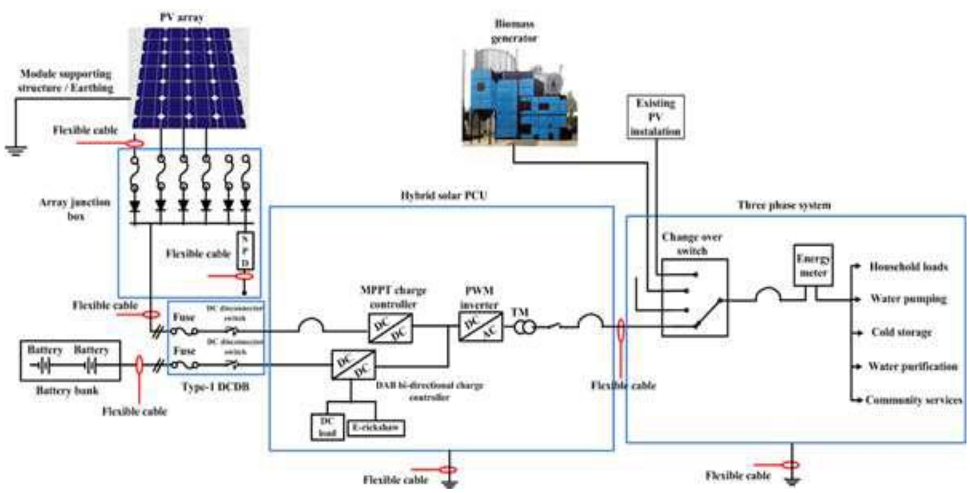

Figure 4 Keonjhar, Odisha: Indian Demo site

4.3 SWOT Analysis for Technical, Social and Environmental Framework

The demand from some sparsely populated regions, where the capacity to pay bills is low, does not justify the investments on the supply side, as building a complete transmission and distribution system takes up immense land and money. The generation costs in a microgrid depend on location, capacity, installation costs, etc., and so it is difficult to generalize the price per kWh from a microgrid. Although microgrids have their benefits, the electricity is not cheap. Combining with storage to counter the intermittent nature of renewable sources often makes them costlier than provision from the main grid electricity. For example, in a 2016 study at Stanford, it was concluded that the average price of grid electricity in village in Gujarat is $0.06/kWh; however, the integration of a solar-battery microgrid would cost the village up to $0.38/kWh. Nevertheless, renewables would still be a good replacement against diesel-only power generation that can cost up to $0.57/kWh. Some believe that the benefits outweigh the additional cost. The electricity eventually enables local shopkeepers to stay open for longer, as they no longer depend on the daylight. In a nation with agriculture as the dominant source of livelihood, electricity from microgrids has also promoted a shift to solar pumps.

Despite all benefits, setting up a formal network of microgrids in India is not without its own challenges. There are regulatory and bureaucratic hurdles to cross, with the challenge of educating people who are receiving electricity for the first time, and encouraging them to adopt a non-wasteful behavior. From a business perspective, there are challenges around scalability, power theft and an eventual extension of the central grid. States often do not disclose how the central grid will expand, making microgrid investments tricky for developers. In many cases, microgrids also face high O&M costs due to little availability of local technicians to look after the systems.

To achieve the objective, this section begins with the identification of obstacles and drivers related to two demonstration sites in India through a set of questionnaire capturing the expert responses from the involved partners who are leading the deployment and demonstration as demo leaders. Evaluation was performed to classify barriers and drivers using SWOT analysis with help of the experts' assessments.

Ghoramara Island, West Bengal: Indian Demo site	
Strength (S)	**Weakness (W)**
• No Grid availability • Small scale of operation • Partial solar panel infrastructure for street lights • Availability of land for microgrid installation • Ideal test bed for the developed ecoTools and solutions • Installation of smart meters partially • Demonstration of EVs – boats, four wheelers with charging station	• Lack of specialized workforce • Financial viability issues • Integration with industrial grade components • Lack of transmission and distribution lines • Stakeholder's missing • Backup generation issues • HHs skewed in two distinct pockets leading to integration, cost issues (two microgrids) • Community is very poor and vulnerable due to very limited income generating sources
Opportunity (O)	**Threat (T)**
• Multiple infrastructure development avenues (charging stations, remote monitoring system, wind turbines)	• Prone to adverse climate changes • Geographically remote and distant location

• Community participation and willingness to pay, local authority support • Scope of energy usage for business operations • Potential of high positive impact on socio-economic and environment sustainability • Scope to define dedicated policy for easy replication in other regions • New business modelling and strategies to develop virtuous cycle	• Logistic issues due to difficult topography for deployment and equipment transfer • Real time data streaming challenging due to lack of internet infrastructure • Potential risk of damage to assets created due to extreme weather • Poverty energy nexus causing vicious cycle which in turn negatively impacts financial viability and socioeconomic sustainability of the microgrid

Table 11 SWOT Analysis of Ghoramara Island, West Bengal, India

Ghoramara is an islanded community away from the mainland and only mode of transportation being ferry, so the mobility is highly constrained creating logistic issues. It is also characterized by severe weather conditions posing a threat to the microgrid and the assets. Access to clean electricity will definitely enhance the welfare and quality of life of the people however, the impoverished population requires handholding for income generating avenues through the acquired electricity. Any intra business activity may not support the community sustainably as the money rotation will happen within the community itself and no overall growth will be visible. Hence, targeted business and transaction models for diverse groups/ individuals need to be designed to promote business activities and develop channels with the mainland and other small to medium enterprises. High scope and opportunity to test and benchmark niche approaches for consistent financial anchoring of the microgrid coupled with the demonstration of innovative technical solutions in the project site.

Distribution and transmission lines depend on the distance which raises the costs measurably. Wiring and pole infrastructure including the pre-paid or smart meters costs are substantial without factoring in the operation and maintenance costs on wiring etc. In such circumstances, for microgrids a viable option can be to ensure low consumption such that even at a high per unit rate, the monthly total cost billed to consumers remains manageable. Many microgrid operators aim for $0.65 – $1.30 per home per month. Microgrid design at Ghoramara assume limits on loads which keeps costs down but limits energy usage growth and also mandates oversight.

Keonjhar, Odisha: Indian Demo site	
Strength (S)	**Weakness (W)**
• Small scale of Operation • Capacity enhancement capability • Ideal testing site for multiple sources • Citizen engagement methodology • Pre-existing transmission and distribution infrastructure - lines, poles, wiring, etc.	• Lack of local participation • Post project completion issues • Less financial opportunities • Willingness to pay only for business/ commercial activities
Opportunity (O)	**Threat (T)**

• Infrastructure of microgrids • Ability to achieve synergy • Local area participation • Mutual agreements with governments • Stakeholder engagement • Achieve financial sustainability and revenue from commercial energy usage • New business modelling and strategies • Smart meter deployment	• Installation, transportation cost, ROI issues, ownership issues • Regulatory framework • National standard codes compatibility • Environmental clearance • Disposal/recycling of components • Lack of specialized manpower • Geographically remote issues • Integration with rest of RES

Table 12 SWOT Analysis of Keonjhar, Odisha, India

The main issue in these remote villages in Keonjhar is lack of stable electric power. The present installed capacity of 30 kWp is barely serving the household activities and a major challenge is the higher tariff of electricity. Another issue is to design power converters with high efficiency at low power range for livelihood applications. The field test is anticipated to demonstrate optimized use of renewable PV solar and biomass power by means of stiff DC-link control capability in standalone mode. The demonstrated solutions, tools, strategies, business models in Keonjhar will enable to develop a socio-economically sustainable model which can be easily replicated in other remote villages in India. Also by coordinating and engaging the village community, local livelihood activities need to be developed, which in turn will enable to build sustainable and profitable local energy systems. Smart meters will be deployed to gather energy consumption data from the villagers to be used for further development of demand side management algorithms. Conversely, lack of community participation and stakeholder engagement act as constraints for the deployment which must be overcome by sensitizing the community for the short term as well as long term benefits of microgrid. Ostracizing the responsible consumption and generation of clean energy results due to comparative financial burden from microgrid vis-à-vis grid electricity.

Some common challenges are observed in microgrid installation at both the Indian demo sites which are common outcome of both fuzzy and SWOT analysis. The accurate siting and precise sizing of a RE based microgrid is very challenging, especially since almost all costs are fixed leading to reduced flexibility from both demand and supply diversity. Over sizing means unmet costs while under sizing means the system lacks scalability or meet sporadic higher demand. Such events will be countered by incorporating safety measures with load options. Microgrids need explicit planning for the energy supply and for system diversity. Battery sizing design with over discharge prevention is yet another issue considering the lifespan, savings and steady solar supply. Another real challenge is the chain of proper supply procurement, allocation, accounting, enforcement, control, and focus on quality service provision.

Set power prices (tariffs) for the grid at least equal to the variable cost of supply at a fossil fuel level. More than creating a culture of paying, this overcomes utility resistance to serving such users, and also improves the benchmark for microgrids (but not enough for viability). For the truly poor, even at low consumption, a separate subsidy as direct benefit transfer can be provided for this electricity. A flat rate billing mechanism though simple but inefficient in capacity and risk allocation. In continuation, cross subsidies can help microgrid operators or third party rural provider to support upfront costs along with low tariffs.

At both the Indian demonstration sites the major barrier to overcome is the financial sustainability. Concerns regarding the practicality or feasibility of microgrids further adds to reservations of project developers. High upfront capital cost restrains serving underprivileged rural consumer without access to electricity despite being a potential market with no/ shortage of electricity supply. Another major issue is that deployment of these microgrids is location specific and will be tailored to fulfil the needs of distinct community, thereby leading to high variance across business models. Unless return over investment (ROI) can be proactively predicted for the microgrids, varying returns will continue to drive off potential benefits. In addition, acquiring government subsidies are very difficult, and usually do not cover the entire demonstrated need of projects. The rural communities do not have networking with formal institutions and agencies and are not capable enough to build business/ commercial channels hence setting sustainable pricing becomes an integral issue.

Further, weather and human intervention based outages or failures are not uncommon, and a key issue is keeping spares accessible. A single village-sized microgrid becomes a very costly proposition in terms of inventory. In addition to billing and collection (rates being poor), physical maintenance of lines is a key challenge especially with leakages and theft of energy, battery and other assets. Many a times unmetered irrigation pumpset loads are politically sensitive issues in view of free agricultural power, hence the aggregate quantum of support needs to be modest for microgrid operations.

In addition to ongoing and fixed deployment costs, there are some costs associated with the social aspects such as training or local manpower. Estimations are difficult on account of scale of the project and varying past experiences of project developers, with other costs like cost of surveying, planning, stakeholder engagement, obtaining permissions and approvals. These barriers, however, have not kept companies from successfully implementing microgrids. While microgrid financing in India does not look to become streamlined any time soon. Cost of payment collection for some Indian microgrid companies has fallen by 60% due to new payment methods such as cell phone collection strategies. Companies have used varying methods of repayment and financing including vendor financing, direct ownership, energy service contracts, power purchase agreements, debt financing, and other alternative energy financiers.

5 Demonstration Sites in EU

A non-interconnected Kythnos island which also includes an off-grid system Gaidouromantra, and three villages in a grid-connected Bornholm island are selected for demonstration of the project's solutions in EU. Kythnos island demo site includes residential consumers, an industrial facility (desalination plant) and small and medium size commercial buildings while the Bornholm demo site includes households, a public building (swimming pool) and a private school. Novel approaches are deployed to optimize network architecture, planning and development based on the opportunities offered by integrated local energy systems and enabled by digitalization and power electronics to contribute in addressing the challenge, as can storage of electricity in all energy vectors e.g. electricity, heating, cooling, water, wastes, etc. Innovative approaches, based on Renewable Energy Communities, in line with the recently adopted Renewable Energy Directive (EU) 2018/2001, can result in attractive business cases for local investments in smart integrated energy systems with weakly or non-existing grid connections.

Policy Brief: Greece, EU

RES operation and remuneration and RES tendering schemes are described in Law 4414/2016 adjusting Greek legislation to the provisions of decision 2014/536/EE. In 2014, a net metering system for autonomous producers was for the first time introduced in Greece. The net metering process is described in FEK B' 3583/2014. Furthermore, "virtual net metering" was introduced in 2016 as an amendment to Law 3468/2006. Especially city/regional councils, schools, universities, farmers and farming associations will be allowed to develop PV and wind power projects located at a considerable distance from the place of the actual power consumption.

Responsibility for operation and management of NIIs has been assigned to the Greek DSO (HEDNO S.A.), which also acts as the island generation, transmission system and market operator in full accordance with the "Non-Interconnected Island Power Systems Management Code", which is issued by the Regulatory Authority for Energy. Law 4513/2018 introduced the concept of energy communities in Greece as a step towards energy democracy. The law aims to enable local actors (citizens, municipalities, local businesses, universities etc.) to get actively involved in the clean energy transition with some special provisions for islands. The Greek government announced in the summer of 2020 the National Plan for E-mobility. This new initiative for cleaner mobility is in line with the EU Green Deal growth strategy and is expected to help Greece achieve transition towards climate neutral economy by 2050. The plan includes extensive subsidies to foster electric mobility in the country. The goal is to achieve one in three new vehicles in Greece to be electric in 2030.

Policy Brief: Denmark, EU

The Danish government has set a number of goals in terms development and transition of the entire energy sector, with a focus on low-carbon technologies and systems. The long term plan for Denmark is to be carbon neutral and self-reliant on renewable energy by 2050. The agreement signed by the parliament in 2012, termed The Energy Agreement, established the policy on the energy framework up to 2020 and provided direction Denmark will take until 2050. By the year 2027, all the electricity in Denmark will be generated by renewable energy sources. The 2018

Energy Agreement was agreed upon in the Danish parliament, defining policies and trajectories for the years after 2020. The government allocated the funding for a goal of reaching a share of renewables in the total energy consumption of 55% by 2030. In June 2020, the Danish Parliament passed the Climate Act that states that Denmark will reduce emissions of greenhouse gases by 70% in 2030, in comparison to 1990.

Current trends and trajectories indicate that Denmark will reach 54% share of renewables by 2030 without any major changes to the existing energy policies. Additional policies that need to be implemented to reach the 70% carbon emission reduction may affect the level of penetration of renewable energy sources. Renewable energy in Denmark is being subsidized through multi-technology tenders for wind power and solar PV. The projections show that the offshore wind will continue to increase, while the number of onshore wind turbines is expected to decrease as per the Energy Agreement from 2018. Main driving factor behind the policy is the reduction of cost of offshore wind. The Energy Agreement also stipulates a plan for building two energy islands in the North Sea, and if realized it will result in surplus of generated electricity in comparison to consumption by 2030. Danish Energy Regulatory Agency regulates the Distribution System Operators in Denmark, and from 2018 it will operate under a newly developed regulatory model focused on efficiency improvements and possibly on apply time-of-use tariffs for all customers.

The district heating system is a major element in Denmark's energy transition objective. 63% of all Danish homes are connected to the district heating system. Use of renewable energy for heating supply became a major priority in the 1990s, and specifically after the Biomass Agreement was passed in the parliament in June 1993. Prior to 2018, the decentralized combined heat and power plants received subsidies for generating electricity. However, policy introduced in 2018 limited the subsidies to those plants that generate electricity using renewable sources. Future trends in terms of district heating indicate that this sector has a big advantage due to the flexibility of fuel usage and heating generation technology.

5.1 Kythnos Island: Greece

Kythnos is a Greek island, (99.4 km^2 – 1608 inhabitants) part of the Cyclades complex in the Aegean Sea with a long history in sustainable energy installations. It hosts the first wind farm in Europe constructed in 1982 and the first microgrid in Europe in 2001, in Gaidouromantra, a small valley next to the coast, in the southern part of Kythnos. Kythnos has been a versatile live testbed for smart grid technologies, which have been developed in the framework of several European projects. Based on this past experience and since it is non-interconnected to the mainland electrical grid, leading to constraints in RES penetration, Kythnos provides an ideal demonstration site and for high TRL applications. The Gaidouromantra islanded microgrid electrifies a settlement consisting of 14 houses with 100% renewable energy coming from PVs and batteries since 2001. Besides being the first microgrid in Europe, in the Kythnos settlement advanced decentralized techniques for DSM techniques were demonstrated for the first time.

Existing Infrastructure

Kythnos island	Gaidouromantra Microgrid
• 5 x 33 kW + 1 x 500 kW = 665 kW wind turbines** • 3 PV stations of 238.25 kW • 5920 kW installed capacity of fossil fuel generation ** Currently the wind turbines are out of order but there is an ongoing effort for repowering	• 7 distributed PV arrays • Two Lead-Acid (FLA) battery banks, one with 1000Ah/48V (main), and one with 539Ah/60V (secondary) • Three-phase, 9kVA diesel back-up generator • Loads (refrigerators, lamps and dwelling pumps) • Load Controllers for protection against overloading or extreme battery discharge

Table 13 Existing Infrastructure at Kythnos Island, Greece, EU

The project aims to increase of energy efficiency by the synergy of electricity with other energy carriers, increase of RES penetration by efficient generation and demand management and increase of population awareness and customer engagement. Tools to be demonstrated in the project are viz. ecoEMS, ecoMicrogrid, ecoPlanning, ecoDR, ecoPlatform, ecoMonitor, ecoCommunity and ecoResilience.

At Kythnos, the energy production system consists of 5,920 kW capacity of fossil fuel generation and 238.25 kW PV. Moreover, 665kW wind generation is currently out of order, but there is an ongoing effort for repowering. Further, Gaidouromantra Microgrid consists of seven distributed PV arrays, two lead acid battery banks, a three-phase 9kVA back-up diesel generator, specific flexible loads and load controllers for protection against overloading or extreme battery discharge.

Available energy vectors such as cooling during summertime plays a critical role in the operation of Kythnos' energy system. Moreover, water treatment in Kythnos is achieved through desalination plants with high operational costs and energy consumption. The optimized and efficient operation of the three energy vectors, cooling, water, and electricity is highly recommended for the island in order to reduce energy costs, to better manage the energy demand and finally increase RES penetration. Additionally, in Gaidouromantra Microgrid each house is equipped with a water pump, which is responsible for replenishing a water tank and in this way supplying water to the household. The residents use the water for some small-scale agricultural activities and gardening. The two energy carriers will be combined and co-optimized for the efficient operation of the local energy system.

Renewable penetration and *citizen engagement*

Studying the operation of Gaidouromantra's Microgrid the main detected issue is that the batteries are frequently overloaded because of the concurrence of many houses' maximum demand. Based on that and according to earlier studies, the users of the microgrid have shown a grid-oriented energy culture and not a culture of autonomous energy supply. Technical Demand Response in combination with behavioral demand response techniques adapted to small scale energy systems will be applied and demonstrated for optimized and efficient energy management. In addition, Microgrid Management System will be developed and demonstrated for optimal microgrid operation taking advantage of the flexible loads and the available energy vectors. Tools and solutions to be demonstrated in this pilot are:

- ecoEMS: Optimization of the energy system operation in Kythnos Island, exploiting the synergies of the energy vectors (e.g. optimal dispatch based on forecasting, economical and technical criteria)
- ecoMicrogrid: Optimized and efficient operation of Gaidouromantra, exploiting the synergies of the energy vectors (e.g. optimal dispatch of the generation units of the microgrid)
- ecoPlanning: For optimizing the mix of energy technologies
- ecoDR: Load Shedding based on Flexible Loads in Gaidouromantra Microgrid and behavioral Demand Response techniques
- ecoPlatform: The platform will be used to keep a consistent database and an integration interface for the used tools
- ecoMonitor: Sensors will be placed to monitor the water quality of Gaidouromantra
- ecoCommunity: To facilitate active involvement of the stakeholders in energy system
- ecoResillience: Local manufactured residential wind turbine for Gaidouromantra, workshops and training to local communities. The goal will be to increase the power capacity of the wind turbine

5.2 Bornholm Island: Denmark

The Danish island of Bornholm has embraced the green agenda for over 30 years, aiming to become a CO_2 neutral island in 2025, and a zero-emissions and climate-friendly community by 2035, while it had been awarded with the 1st Prize of RESponisble Island. Bornholm (40000 inhabitants – 589 km^2) is a whole community consisting of one municipality with hospital, police force, court of justice, educational institutions and utility companies. All sectors of society are engaged in a penta-helix model, bringing together science, public institutions, business and civil society aiming at co-creating and empowering stakeholders, as a means to uphold – and hand down a sustainable island for future generations. The Bornholm energy system development is headed by its municipality and multi utility company. Bornholm has a total energy demand of 900 GWh per year including power, heat and transportation. Bornholm connects to the Scandinavian electricity grid through a submarine power cable to Sweden, but is also capable of running the electric system off grid. Energy production system consists of a wood chip fueled combined Heat and Power plant, and decentralized district heating grids fueled with 100% local produced biomass. The energy system combines proven technologies and innovative solutions, system integration, local biomass and an advanced simulation model.

The objective is creating synergies and integrating the energy vectors: Electricity, district heating, biomass - forecast, balancing and integration of increasing PV - production through Østerlars heat grid. This field test will demonstrate local services of power control, peak shaving and optimizing use of renewable biomass and solar power, by means of intelligent control capability. Forecast of production from a PV plant by means of meteorological data of irradiance, will be used for the control of electrical boilers in Østerlars heat plant, for balancing and absorbing the fluctuating electricity production and store it as heat in the district heating system. The District heating consumers in the Østerlars grid all have remote read digital meters, enabling detailed analysis of data about consumption, temperatures, and flow in the grid. The consumers are also equipped with identical “heat units” containing 100 liter hot water storage tanks, and Danfoss ECL computes controlling the charging of the tanks, and temperature level of incoming water to the household radiator system.

Existing Infrastructure

Bornholm island - power Østerlars local grid – heat (Demo)	Østerlars Heat Plant
• 37 MW from 35 larger wind turbines. Private and public owned • 8 MW from app. 1000 rooftop PV stations • 15 MW from two private PV production plants • 3 MW from Biogas plant Central Heat & Power plant • 35 MW from woodchip fueled boiler • 58 MW capacity of fossil fuel generation • 60 MW capacity import/export via sea cable	• MW straw fueled boiler (with condensation) • 2.4 MW electric boilers (backup) • 1-2 MW wood pellet fueled boiler (backup) • 80 MWh in hot water storage tank – 1500 m^3 • 93 kW power from rooftop PV • *Loads:* households, trade, institutions, and a public swimming pool – totally 600 consumers.

Table 14 Existing Infrastructure at Bornholm Island, Denmark, EU

Electricity production assets integrates 37 MW wind turbines, 23 MW PV, 3 MW biogas plant, 58 MW capacity of fossil fuel generation and 60 MW capacity import/export via sea cable. The optimized and decarbonized operation of four energy vectors - district heating, electricity, biomass and transport - is highly recommended for the island, so it will be possible to integrate and fully use increased RES capacity from new PV-plants and wind turbines (offshore). Biomass (local woodchips, straw, and manure) is vector for heat (primarily) and electricity production in district heating, CHP, and Biogas-plant. Electricity is a vector for district heating via electric boilers, heat pumps, and in the future waste heat from P2X production.

Renewable penetration and *citizen engagement*

Bornholm already has a very high penetration of RES presently. District heating is based on local renewable biomass, and a little waste incineration. Local electricity production is based on biomass, wind and sun, and covered 70% of the electricity consumption in 2019. Citizens on Bornholm have invested in energy production for the last 30/ 40 years. At present there are about 1000 households with rooftop PV panels with an effect of approximate 8 MW. There are 50 households with their own wind turbines of up to 25 KWH. Both PV and wind turbines are grid connected. An important local impact is the local fuel supply to district heating and CHP - straw and woodchips. Current consumption in the heat and power plants of locally produced biomass is approximately 20000 tons/year straw and 50000 tons/year woodchips. With the current price of straw at approximate 75 €/ton, and woodchips at 60 €/ton (at 45% water), the value of the locally produced fuels are app. 4,500,000 €/year, furthermore there is a lot of local labor involved in production and transportation of straw and woodchips. A newer 50 kW PV installation at the public indoor swimming pool has been raised by crowdfunding among local citizens. Tools and solutions to be demonstrated in this Demo are:

- ecoEMS: Optimization of the energy system operation in Bornholm Island, exploiting the synergies of the energy vectors (e.g. optimal dispatch based on forecasting, economical and technical criteria)
- ecoMicrogrid: Optimized and efficient operation of the Østerlars heat plant and heat grid, exploiting the synergies of the energy vectors (e.g. optimal dispatch of the integrated generation units for the grid)
- ecoDR: Creating flexibility in the Østerlars heat grid by Demand Response techniques
- ecoPlatform: The platform will be used to keep a consistent database and an integration interface for the used tools
- ecoMonitor: Sensors will be placed to monitor irradiation, enabling forecast and control of electric boilers in Østerlars heat plant
- ecoCommunity: Workshops/ training of the participating consumers in local communities. The goal will be to increase the knowledge and engagement in the local communities

Figure 5 Bornholm Island, Denmark: EU Demo site

5.3 SWOT Analysis for Technical, Social and Environmental Framework

Despite the fact that Kythnos has a long history in renewables and low-carbon applications, still it is quite dependent on diesel generators and fuel oil, making the variable cost of energy in the island very high, like most of the Non-Interconnected Islands (NIIs). By applying "smart" and efficient techniques and technologies for energy management, there is a lot of headroom for renewables integration. Within "RE-EMPOWERED" advanced Energy Management System applying the technical restrictions and economic criteria, capitalizing on the available energy vector synergies, will be demonstrated to optimize the operation of the local energy system, allowing further renewable energy integration and cost reduction of energy production. In addition, innovative Demand Response techniques will be implemented for even better energy management through the engagement of local energy consumers and producers, leading in the development of new attractive business cases. The case of Kythnos can pose the prototype and can be replicable in all the NII of Greece.

To achieve the objective, this section begins with the identification of obstacles and drivers related to two demonstration sites in EU through a set of questionnaire capturing the expert responses from the involved partners who are leading the deployment and demonstration as demo leaders. Evaluation was performed to classify barriers and drivers using SWOT analysis with help of the experts' assessments.

"RE-EMPOWERED" will accelerate the digitization and energy transition of Kythnos' energy system. Building on the existing experience and proven technologies developed within past EU projects, the tools and business models that will be upgraded and demonstrated in the framework of "RE-EMPOWERED" will lead to higher technological and efficiency level and moreover it will increase the maturity level to develop a structured energy community with active engagement in its core. The demonstrated solutions, tools, strategies, business models in Kythnos will synthesize an economically sustainable and attractive multi-layer architecture that will be replicable in all non-interconnected islands in Greece and elsewhere.

Kythnos, Greece: EU Demo site	
Strength (S)	**Weakness (W)**
• Successful testing of multiple innovations for the specific site • Ability to achieve synergy from existing infrastructure • Small scale of operation • Several complementary projects ongoing	• Lack of specialized local workforce • Insufficient participation of local community in decision making process
Opportunity (O)	**Threat (T)**
• Operating constraints of thermal generators • Existing multiple solutions for Smart grids in the market • High emission cost of fossil fuel • Network stability issues • Acceptability of innovative solutions by customers • Early mutual agreements • High environmental awareness • Strict Legal provisions for emission standards • New business modelling and strategies	• High transportation cost, installation cost, economies of scale • No Regulatory framework for demand side • Challenging weather conditions for equipment - high salinity and humidity • Clean energy transition issues for local community (e.g. gas stations)
Kythnos Gaidouromantra MG, Greece: EU Demo site	
Strength (S)	**Weakness (W)**
• Microgrid operation expertise at specific site • Sufficient data regarding usage • Involvement of local community at planning phase	• Components failure • Ensuring adequate maintenance • Customer dissatisfaction issues • Inadequate business Model • Citizen engagement issues

	• Lack of backup generation
Opportunity (O)	**Threat (T)**
• Good morphology for installing PV • Great solar potential • Availability of a Distribution network • A fully functional infrastructural part	• Environmental licensing complexity concerns due to the proximity to shoreline • Land and infrastructure ownership issues • Site specific resource utilization concerns

Table 15 SWOT Analysis of Kythnos Island, Greece, EU

The demonstration in Bornholm Island in Denmark will provide means of integrating more electricity from RES, in a community that already have a high penetration of RES. On Bornholm a group of citizens, with support from the municipality, are now developing a 100 MW wind turbine park (offshore) based on local funding, to be ready in 2025. New PV-parks are also planned. This means that in the near future the sea cable to the mainland will not have enough capacity to export electricity from RES on Bornholm, when the production from wind and sun is high, so ways to integrate electricity with other energy carrying vectors, e.g. district heating and transport, has to be found, or else it will be necessary to curtail RES in periods and thus waste the energy. All communities will face this problem at some point of time in the future, and it is essential to develop a multitude of solutions for different energy systems and communities.

Bornholm Island, Denmark: EU Demo site	
Strength (S)	**Weakness (W)**
• IT and SCADA infrastructure • Presence of different energy vectors with scope of co-optimization	• Limited participation • Financial obstacles • Employee skills
Opportunity (O)	**Threat (T)**
• Reduced Carbon-emission legislation • Increase in sensor deployment • Control and forecast opportunities • Sector coupling of district heating and electricity • Community engagement through new technologies and business models • New business modelling and strategies	• Extreme Seasonality • Cyber Security • Long term viability • Integration of district heating into demand management framework • Disposal/ recycling of components

Table 16 SWOT Analysis of Bornholm Island, Denmark, EU

Citizens have expressed some degree of willingness-to-pay (WTP) for renewable energy. This could be attributed to the wider EU energy policy framework, consistent in promoting the diffusion of RES through the provision of subsidies, incentives and the funding of large scale investments. Liberalized markets consumers can choose renewable energy providers, contracts and tariffs suggesting their absolute will to support renewables. Hence, what induces individuals to actually pay for renewables is the positive relationship with pro-environmental attitudes by strategically raising public environmental awareness. Citizens here, are paying for renewable energy, which is produced by local energy projects or offered by utilities owned by local bodies in comparison to large investor owned companies. Therefore, this has increased the share of individuals who pay for renewable electricity in the EU demo sites.

In the EcoGrid projects it is shown, that it is possible to engage the citizens and create flexibility in the power grid by controlling household electricity consumption – in this demo attempt will be to expand the scope to create flexibility and synergy in both power grid and heat grid, and engage citizens and community to participate in the project. A number of consumers in Gudhjem (energy community) will be recruited for the demonstration, and upgraded with remote controls, to provide access to demand-response in the grid, for balancing heat input from PV via electric boilers. Two consumers are already recruited, the public indoor swimming pool in Gudhjem, and the local school in Østerlars. On the production side short time solar forecasting of a presumed 20 MW PV plant will enable peak shaving and avoids reinforcement of the weak electrical grid, by means of controlling the 2.4 MW water boiler at the Østerlars district heating plant.

6 Evaluation of Obstacles to Innovation and Drivers: ecoTools

Experts now argue that technologies such as solar, wind, and small-scale hydropower are not only economically viable but also ideal for rural areas. Renewable Energy Technologies (RETs) are cost-competitive with conventional energy sources in applications such as solar water heating, off-grid electrification with solar photovoltaics (PV), small-scale biomass power generation, biofuels, grid connected/ off-grid wind power. Despite technological developments and economic viability for several applications, there is existence of numerous types of barriers for renewable energy penetration. These barriers to renewable energy may vary across technologies and countries. This section focuses on identification of these barriers and possible ways to overcome them for exploration and exploitation of innovations in RETs.

Innovation diffusion depends upon the RETs technological, techno-economic, or economic potential. Technological potential refers to the highest order of possible usage level universally, without any constraints (cost, reliability) followed by techno-economic potential observed when technology is universally used in competitive markets in absentia of market related barriers and lastly economic potential attained in an environment free from market failures and distortions. Scientific and technological progress in terms of improved technology and reduction in costs can continuously improve all three types of potentials. The objective of this section is the determination and evaluation of the obstacles to innovation and drivers from three aspects – technical, social and environmental of the innovative solutions ecoTools that will be deployed and demonstrated in the identified four demo sites in India and EU for local energy system.

6.1 DEMATEL Analysis based Technical, Social and Environmental Framework

In the project RE-EMPOWERED, efficient tools and economic solutions will be developed aiming to increase renewable energy penetration in local energy systems and foster decarbonization. The ecoToolset to be demonstrated in the pilots are jointly developed by involved European and Indian partners. Several solutions with innovative characteristics will reach high TRL during the project implementation, aiming to reach the EU and India markets shortly after the completion of the project. Industrial partner will lead the commercialization of several products - ecoEMS, ecoMicrogrid, ecoPlanning, ecoConverter, ecoVehicle, ecoDR, ecoMonitor - will license the tools to Indian companies as members of the stakeholder group for commercialization. The tools have high innovation potential and include aspects not existing in the EU and Indian markets in view of the current market status. Most notably, four solutions will reach TRL 8 (ecoEMS, ecoConverter, ecoPlatform, ecoVehicle), three solutions will reach TRL 7 (ecoMicrogrid, ecoDR, ecoMonitor), while one solution (ecoPlanning) is already at TRL 9. Tools will be installed in the four demo sites selected considering diversity. It's a technological and financial challenge for the electricity network to integrate more renewables, but it is also an opportunity to optimise the electricity system operation in synergy with other energy carriers/ vectors to increase the hosting capacity for renewables, not just for electricity but also for heating/ cooling, transport and/or industry in a sector coupling approach. Target objectives include the increase of RES penetration in energy mix, advanced optimization algorithms, optimal operation of multi-energy systems to achieve cost minimisation, new types of flexibility, improve efficiency and power quality with hardware ecoTools. Besides, digital ecoTools solutions for innovative network architecture and planning, multi energy carrier integration, allow interoperability, system integration and community engagement will be developed. Several solutions with innovative characteristics will reach high TRL during the project implementation, aiming to reach the EU and India markets after the completion of the project. Moreover, knowledge, results and additional insights will feed into the project's social interactions/ activities, stakeholder engagement, active prosumers, training, special requirements of energy disadvantaged communities, monitoring Internet of Things (IoT) and Information and Communication Technology (ICT) based technologies, and dissemination and communication activities to foster adoption of community based energy solutions.

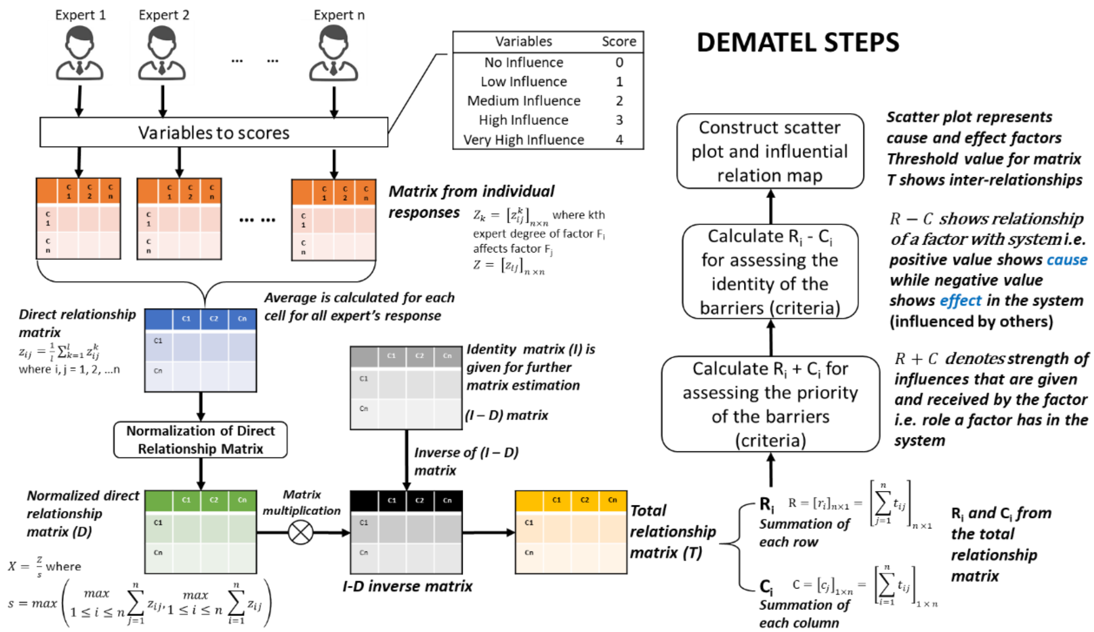

Figure 6 DEMATEL Methodology

In this section, analysis begins with identification of the barriers and drivers related to the ecoTools through a set of questionnaire capturing the expert options from the involved partners who are leading the innovation development as ecoTools leader for the ten solutions – hardware as well as software/ platform. After that, evaluation was performed to find key barriers and drivers with help of the experts' assessments. Finally, the DEMATEL method is used to analyze the cause–effect relationships between these key barriers and drivers. The motivation for conducting DEMATEL analysis comes from the earlier analysis of fuzzy TOPSIS and SWOT. Both of the earlier techniques focus upon the macro and meso to micro (specific to demo sites) level barriers posing risk and uncertainty for the development and deployment of the microgrid local energy system. However, DEMATEL specifically examines the identity of a barrier with respect to the entire system in which it is hindering along with the influential inter-relationships for the developed ecoToolset. Hence, DEMATEL is one step deeper analysis for the ecoTools i.e. the innovations driving the deployment of microgrid at four different demo sites in the project RE-EMPOWERED.

So, it becomes a funneling process with filtering of the obstacles at macro, meso and micro level in the context of policy, regulatory, technical, social, environmental aspects aligned well with the national/ regional perspective further to demo sites and finally at the ecoToolset level. While the drivers have been considered explicitly for the demo site and ecoTools whereas implicitly for the national/ regional level.

DEMATEL is a recognized and comprehensive method to obtain a structural model that provides casual relationships between complex real-world factors when there is an interdependence among them. It is superior to other techniques since it accounts for the interdependence among the factors of a system via causal diagram, which is overlooked in traditional techniques [60]. This method finds out the critical factors of the structure with the help of an inter-relationship diagram. Key steps involved is the computation of direct relationship matrix followed by normalization of it as shown in Figure 6. Further, normalized direct relationship matrix is utilized to estimate total relationship matrix based on which the influential relationship map is obtained depicting cause and effect factors. This technique is used here to analyze the primary as well as secondary cause and effect influence on the identified obstacles to innovation along with drivers of the developed ecoTools. This will further help to avoid some of the barriers which could be potential risks during product development and deployment process at demonstration site. The counteractive influence of the drivers will guide the developers to adopt some of the early measures in order to avoid deviations. The advantage of decomposition of a barrier into cause – effect helps stakeholders to understand and respond to easily. Another advantage is that measures to overcome a barrier can be identified easily and removal can be worked out.

No.	ecoTools specific obstacles to innovation	R_i	C_i	$R_i + C_i$	Priority	$R_i - C_i$	Identity
TO1	Handling diversity of assets (storage, peak, load, generation, conservation, reliability)	3.305	3.805	7.111	4	-0.499	effect
TO2	Demand management and forecasting issues	3.235	4.258	7.494	2	-1.023	effect
TO3	Demo site specific variations, functions, energy vectors, remoteness, capacity, infrastructure, equipment transfer, operating constraints	3.882	3.776	7.659	1	0.106	cause
TO4	Interoperability issues (SCADA, sensors)	3.625	3.552	7.177	3	0.073	cause
TO5	Co-optimization with other energy vectors	3.786	3.115	6.901	7	0.671	cause
TO6	Cybersecurity issues	3.611	3.297	6.908	6	0.313	cause
TO7	Data protection, privacy issues and complex/ non-existing policy regulation	3.502	3.455	6.958	5	0.047	cause

SO1	Low local community participation in energy market	2.253	3.143	5.396	10	-0.889	effect
SO2	Limited acceptance of technology (load shedding, cost, low value)	2.542	3.639	6.181	9	-1.096	effect
SO3	Limited access to information and funding instrument	3.740	3.019	6.760	8	0.720	cause
EO1	High seasonality, generation fluctuations, extreme weather conditions (temperature, wind, flooding	3.719	1.646	5.365	11	2.072	cause
EO2	Pollution issues	2.056	2.552	4.609	12	-0.495	effect

Table 17 DEMATEL Analysis for Obstacles to Innovation of ecoTools

Based on the DEMATEL analysis as observed from Table 17, technical obstacles are dominating in terms of the priority followed by the social and environmental barriers to innovation. This depicts that both hardware and software/ platform tools are characterized by their core barriers. The foremost critical barrier is the demo specific conditions such as variations, functionalities, infrastructure, remoteness, and operations, will highly impact deployment, installation and functioning of the developed ecoToolset. This will vary across the demo sites and only tailored solutions can be undertaken to resolve the specific issues, no generic approach will be a working strategy. Another technical issue is the demand management and forecasting issues which are critical for overall local system efficiency. Next is interoperability issues in domains of demand response for energy adequacy and the injection/ consumption of energy, and linking the developed dynamic pricing scheme with the critical and non-critical loads of different energy systems. It also includes challenges of extending traditional SCADA interface of electric distribution systems to include other energy vectors. To link all the ecoTools for performing consistent analysis and control of the different tools, particular attention to cybersecurity and risk, both in data acquisition and supervisory control needs to be paid subsequently. Cybersecurity and data privacy are the next level barriers. Moving to some of the minor obstacles pertaining to social and environmental aspects, limited access to information, funding instrument, limited acceptance of technology and low community participation will be difficult to handle with a single stop gap solution as it involves community perception and behavioral perspective. Multi-pronged approach can alleviate these barriers as it is not possible to completely eliminate these barriers subject to dynamicity of the context. Several actors need to play an active role at different levels to develop capabilities to overcome these hindrances. They also have high degree of variability in terms of causing impact across the ecoToolset in different demonstration sites depending upon the intrinsic strengths and weaknesses of specific demonstration sites in India and EU.

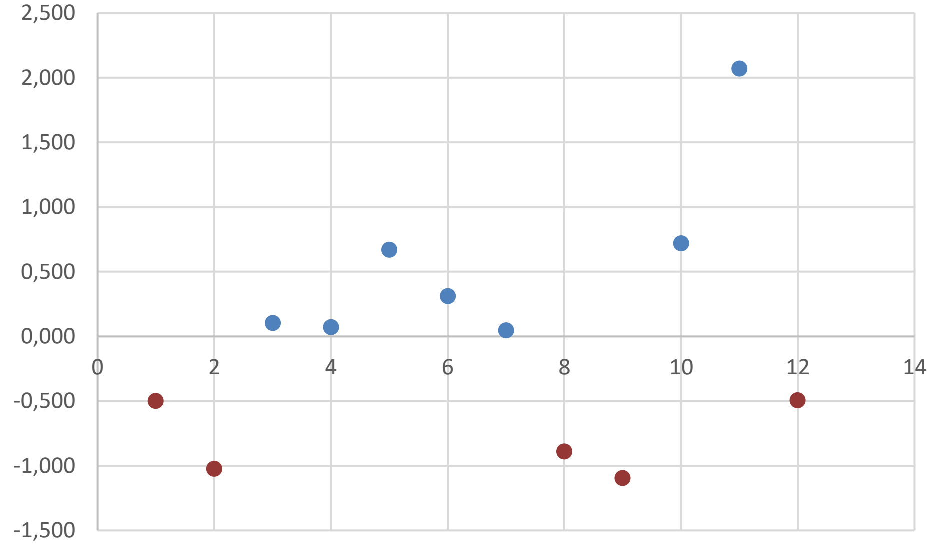

Figure 7 Cause and Effect Identity of Obstacles to Innovation: ecoTools

Looking at Figure 7, the distribution of the identified barriers is done into cause and effect criteria whereby ones with positive $R_i - C_i$ value are the causal criteria while the ones with negative values are the effects. This inter-relationship is very important to comprehend as it suggests what criteria obstacles have the power to be source/ origin manifesting primary impact. Typically, TO3, TO4, TO5, TO6, TO7, SO3 and EO1 are the cause barriers while remaining five are the effect barriers which are secondary in nature having indirect impact. The levels seems to be in correct order stemming from the nature of the obstacles.

	TO1	TO2	TO3	TO4	TO5	TO6	TO7	SO1	SO2	SO3	EO1	EO2
TO1	0.250	0.388	0.319	0.327	0.270	0.283	0.307	0.255	0.271	0.268	0.162	0.206
TO2	0.318	0.277	0.324	0.338	0.283	0.275	0.282	0.258	0.265	0.219	0.176	0.220
TO3	0.353	0.418	0.290	0.345	0.337	0.373	0.359	0.303	0.370	0.321	0.149	0.265
TO4	0.380	0.420	0.360	0.264	0.308	0.343	0.314	0.239	0.339	0.296	0.166	0.195
TO5	0.384	0.431	0.390	0.377	0.238	0.323	0.323	0.303	0.341	0.279	0.167	0.232
TO6	0.351	0.406	0.347	0.344	0.286	0.243	0.357	0.285	0.358	0.278	0.150	0.205
TO7	0.341	0.369	0.312	0.318	0.312	0.339	0.246	0.298	0.343	0.298	0.119	0.209
SO1	0.218	0.247	0.232	0.175	0.148	0.159	0.225	0.143	0.259	0.186	0.072	0.189
SO2	0.268	0.315	0.228	0.198	0.166	0.192	0.234	0.247	0.179	0.192	0.093	0.230
SO3	0.316	0.386	0.358	0.341	0.291	0.343	0.346	0.314	0.371	0.225	0.199	0.251
EO1	0.388	0.406	0.396	0.352	0.319	0.286	0.279	0.309	0.345	0.274	0.124	0.241
EO2	0.240	0.195	0.221	0.174	0.156	0.139	0.184	0.189	0.198	0.186	0.068	0.107

Threshold (alpha) Value = 0.272

Table 18 DEMATEL based Importance for Obstacles to Innovation of ecoTools

Further, the 12 barriers have been observed for their relative importance and either conjoint or unilateral influencing interaction as observed in Table 18. For this, the values form each of the cell in the table is compared with the threshold alpha value estimated to be 0.272. Obstacles showing higher values are considered to have significant impact on the corresponding obstacle and with itself is not considered but it has a rebound effect. The relational influence among the obstacles may not be directly mapped with the earlier fuzzy and SWOT analysis however, such inter-linkages could be indirectly linked as observed through prioritization of obstacles along with the categorization as weaknesses and threat.

These interrelationships which are mutual or one way can be clearly depicted in the Figure 8 where it is highlighted that almost all the technical obstacles have mutual impact except in one case of TO5 over TO1. Besides TO1 and TO2, other technical obstacles are the cause i.e. the origin of the direct hindering effect is from those TO3 to TO7 obstacles while the remaining two have indirect hindering effect. Now, this revelation is of great importance and knowledge as the decision makers can efficiently utilize and allocate resources in a cost effective manner and simultaneously also can plan to mitigate the higher order risks in comparison to other medium or low risks. This will not only ensure to achieve the goals but will help in well-organized risk diversification with short term and long term perspective. Because in any innovative product development the first and foremost objective is technical feasibility followed by the economic viability. Similarly, from socio-environmental view, SO3 and EO1 are the causal criteria while SO1, SO2 and EO2 are the effect criteria. These findings quite go well with the expectations as main bottlenecks are the availability of funding options and information which is a rich resource on which depends many technical decisions pertaining to forecasting, generation, demand, supply, pricing, penetration, etc. Further, many demo site specific challenges are uncontrollable hence accounting for undiversifiable risks and uncertainties. On the contrary, lack of community engagement, low technology acceptance and negative externalities like air, water pollution, etc. can be sensitized over time and aggressive awareness, knowledge creation, cost over benefits, behavioral change, etc. can help to overcome these to a large extent. However, these are grass root deeply ingrained issues which can be possibly removed with consistent efforts or their hindering effect can be subsided gradually with time and systematic practice.

In Figure 8, one more feature can be observed that is the inter-obstacle interaction besides intra-obstacle linkages. Social and environmental obstacles among themselves have few one way or no interaction. SO3 impacts both SO1, SO2 and mutually TO7 (first socio-technical relation) but is affected by TO2, TO3, TO4, TO5, and TO6. This clearly reveals the criticality of financing for every activity as well as access to information for realization of the technical requirements. In addition, SO2 is influencing only TO2, may be due to the fact that the limited acceptance to technology influences hugely demand side management and prediction. SO1, SO2 and SO3 receives impact from EO1 (socio-environmental effect). Interestingly, EO1 tends to impact all the technical and social barriers showing huge significance of weather adverse conditions in RE generation/ penetration while concerns the community as well for believing the actual benefits of the technical solutions coupled with financial access certainty and therefore low interest in installation and implementation of such energy projects. EO1 do not get influenced by any other criteria barrier. Hence, to overcome it, concrete structural planning, minimal risk location siting, use of indigenous knowledge of communities while product development, piloting, disaster management preventive behavior needs to be well placed. EO2 stands alone with nether impacting any barrier nor getting influenced, which depicts the possible negative externalities like pollution etc. are issues which requires heavy motivation for demonstrating individual and collective responsibility towards both consumption and production of clean energy alternatives.

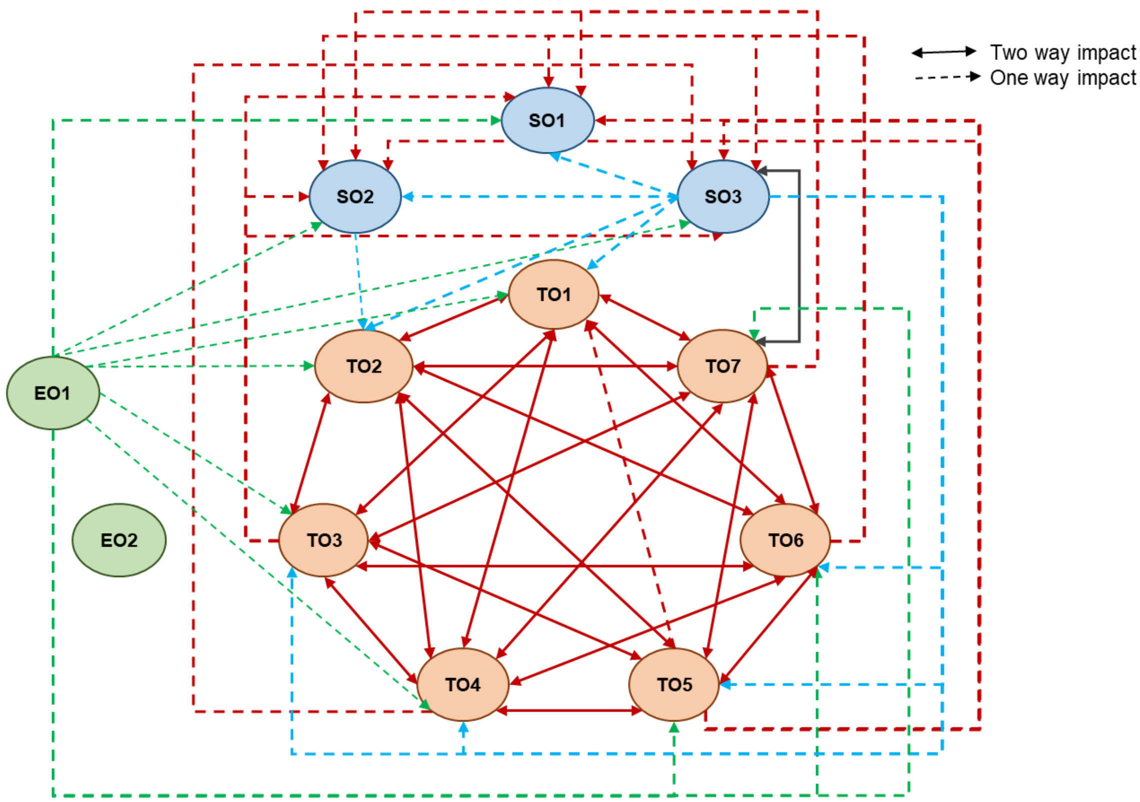

Figure 8 DEMATEL based Technical, Social and Environmental Obstacles to Innovation Framework: ecoTools

Since there are few prominent obstacles operating, therefore, it is imperative to identify and understand the existence of drivers who have the capability to overcome some of the barriers mentioned in the above section. However, the study undertakes a dive into drivers' interaction and significance as analyzed for the obstacles. Based on the DEMATEL analysis as observed from Table 19, top ranking driver is SO3 i.e. energy saving and DR participation followed by the technical drivers which are dominating in terms of the priority. Environmental drivers have lower ranks and same for the other two social drivers. This depicts that both hardware and software/ platform ecoTools characterized by their core technical barriers can be countered by some of the available technical drivers and their hindering effect can be significantly reduced. Surprisingly, TD4 (resolving on-site deployment issues) and TD6 (establish communication infrastructure) received lower priority but later clarifications were sought and it was observed that these are very critical issues requiring humungous efforts from all the involved stakeholders' hence solutions for these needs to be ensured much prior to deployment of ecoTools as such drivers cannot yield the desired result in case planned at a later stage.

Therefore, they have to be incorporated during the pre-planning and nascent stage of product development leading to several simulated iterations undertaken to minimize the unwarranted risks during the actual deployment as the real environment is dynamic and will tend to change. Hence, accurate research, planning, prototype building, defining functionalities, must be accommodated except for some execution and operational activities. Infrastructure needs to be built in much ahead of deployment otherwise microgrid will not be functional.

Among other technical drivers – TD1, TD2, TD3 and TD5 – are the high rankers. These possess potential to overcome the variability, load and security issues, providing flexibility, generation gap, efficiency, etc. Next in priority are the two environmental drivers though medium to low i.e. ED2 (low cost renewables integration for emissions reduction) and ED1 (exploiting low emission electricity sources).

No.	ecoTools specific Drivers	R_i	C_i	$R_i + C_i$	Priority	$R_i - C_i$	Identity
TD1	Multi-objective optimization strategy	3.692	3.994	7.686	2	-0.302	effect
TD2	Robustness and integration of microgrid (security, load etc.)	3.780	3.625	7.405	4	0.155	cause
TD3	Expansion of energy management system to different sectors	3.150	4.293	7.444	3	-1.143	effect
TD4	Resolving on-site deployment issues	3.003	2.796	5.798	9	0.207	cause
TD5	Innovations in small scale yields effective outcomes & flexibility	3.994	3.391	7.386	5	0.603	cause
TD6	Establish communication infrastructure	2.212	3.143	5.355	11	-0.931	effect
SD1	Training and education of locals/ users	2.712	2.029	4.742	12	0.683	cause
SD2	Acceptance of energy conservation technologies	3.161	3.534	6.696	8	-0.373	effect
SD3	Energy saving and DR participation	3.897	4.250	8.147	1	-0.353	effect
ED1	Exploiting low emission electricity sources	3.498	3.400	6.897	7	0.098	cause
ED2	Low cost renewables integration for emissions reduction	3.586	3.420	7.007	6	0.166	cause
ED3	Legislative structure and mutual agreements	3.355	2.163	5.518	10	1.191	cause

Table 19 DEMATEL Analysis for Drivers of ecoTools

They target emissions reductions specifically via usage of more renewables on some regular basis which requires the mindset and behavioral change of the consumers to embrace such appliances and assets. This may not be necessarily a cost-effective option due to high switching cost, habitual mentality, ease of use, and other associated risks. So, these drivers need to be made so effective to actually exhibit advantages which requires a top-down approach for creating a profitable as well as attractive market for such technologies and commercial products. Market linkages becomes of hyper importance to achieve the goal of RE penetration and integration in consumer's lifestyle. One example is towards the creation of sizable and profitable market for electric vehicles however, due to lack of proper pricing, resourcing of parts, supplier issues, supply chain management, targeted policies though Scrap Policy is announced in India but ground level implementation remains an area of concern.

A contradictory finding is the least priority i.e. last rank of social driver SD1 (training and education of locals/ users) and for environmental driver ED3 (legislative structure and mutual agreements). The results may be subject to some of the existing regulatory issues and highly dominating barriers. Since, the legislature and agreements are more complex areas which necessitates the action from higher authorities who needs to safeguard the interests at larger scale and population. These are no doubt critical drivers but in the list of 12 drivers identified for innovative product development ecoToolset, it is possible that the R&D and commercial launching of these technologies are autonomous to the extent that they already follow the national/ international standards and quality control to reach high TRL. Pure product development technical training is not required however acceptance and usage of technology is needed by the communities.

Many ecoTools are much complicated hence full range of engineering training is neither feasible nor fruitful to the communities. Moreover, market for such products is liberated but integrated to outreach new segments. So, training and education to local and end users is definitely required but the delivery requires focus on ease of use, handling of some operational and maintenance issues. It is o fhigh significance to whom the training is imparted, for what purpose and how it is done. Simply pushing what is felt necessary and imposing on consumers without giving them choice mostly becomes an unproductive and futile exercise. Hence, mode of contribution, communication, engagement, generating social capital, emotional quotient for ownership, needs to be brought in while designing the modules. Any regular training with all the above missing elements will be easily forgotten and create least impact and value. Hence, novel approaches and new elements should be used with more focus on psychological, socio-cultural, local beliefs, indigenous knowledge, capability building. Innovative methods for knowledge exchange, information dissemination and sensitizing the communities must be developed with the ease of understanding and use.

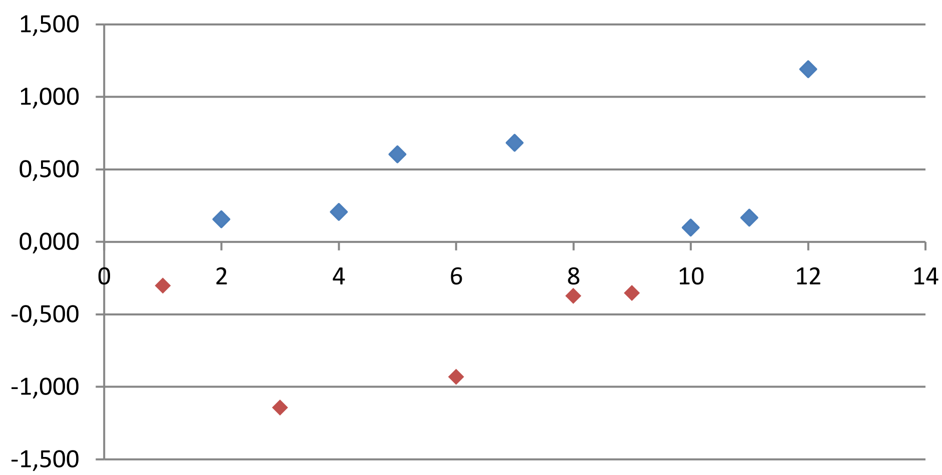

Figure 9 Cause and Effect Identity of Drivers: ecoTools

Looking at Figure 9, the distribution of the identified drivers is done into cause-and-effect criteria whereby ones with positive $R_i - C_i$ value are the causal criteria while the ones with negative values are the effects. This inter-relationship is very important to comprehend as it suggests what driver criteria have the power to be source/ origin manifesting primary impact. Typically, TD2, TD4, TD5, SD1, ED1, ED2 and ED3 are the cause drivers while remaining five i.e. TD1, TD3, TD6, SD2 and SD3 are the effect drivers which are secondary in nature having indirect impact. The priority at first may seem to be misleading but on deep diving it appears to be more rational stemming from the scale and nature of drivers.

Further, 12 drivers (Table 20) have been observed for their relative importance and either conjoint or unilateral influencing interaction as observed. For this, the values form each of the cell in the table is compared with the threshold alpha value estimated to be 0.278. Drivers showing higher values are considered to have significant impact on the corresponding driver and with itself is not considered but it has a rebound effect.

The interrelationships which are mutual, or one way can be clearly depicted in the Figure 10 where it is highlighted that except TD6 (not influencing) SD1 and ED3 (not influenced) other drivers are influenced and/ or influencing one another. Thus, TD6 is effect while SD1 and ED3 are the cause driver criteria having primary impact.

	TD1	TD2	TD3	TD4	TD5	TD6	SD1	SD2	SD3	ED1	ED2	ED3
TD1	0.292	0.347	0.411	0.260	0.314	0.285	0.167	0.316	0.414	0.349	0.360	0.178
TD2	0.396	0.275	0.428	0.306	0.343	0.312	0.169	0.318	0.392	0.313	0.336	0.190
TD3	0.336	0.297	0.269	0.225	0.292	0.255	0.146	0.277	0.323	0.273	0.276	0.183
TD4	0.315	0.323	0.333	0.169	0.250	0.267	0.168	0.246	0.317	0.203	0.244	0.167
TD5	0.395	0.396	0.455	0.328	0.269	0.317	0.188	0.343	0.410	0.335	0.350	0.209
TD6	0.234	0.228	0.257	0.163	0.171	0.137	0.108	0.183	0.234	0.180	0.182	0.134
SD1	0.282	0.221	0.258	0.215	0.189	0.219	0.113	0.296	0.325	0.213	0.205	0.176
SD2	0.335	0.246	0.342	0.201	0.242	0.262	0.206	0.221	0.362	0.275	0.283	0.185
SD3	0.387	0.366	0.408	0.254	0.351	0.289	0.224	0.360	0.327	0.370	0.353	0.206
ED1	0.365	0.321	0.378	0.206	0.346	0.246	0.171	0.324	0.400	0.242	0.312	0.189
ED2	0.353	0.335	0.384	0.228	0.333	0.261	0.174	0.338	0.389	0.343	0.246	0.202
ED3	0.304	0.270	0.369	0.242	0.292	0.295	0.195	0.311	0.357	0.302	0.274	0.143

Threshold (alpha) Value = 0.278

Table 20 DEMATEL based Importance for Drivers of ecoTools

Another interesting phenomenon observed from the influential relation map is there are many inter-drivers interactions leading to cumulative effect with respect to the techno-social, social-environment, and techno-environment. It reinforces that the stated drivers have strong potential to spillover the mitigation outcome not only in their own context but also on others. SD3 is one of the social driver with maximum mutual indirect relation with the technical as well as environmental drivers. Similarly, ED2 and ED3, two environmental driver is having most direct influences on technical and social drivers. Here, social and environmental drivers are more active in terms of influencing and interacting with technical drivers, showing that for removal of technical bottlenecks and barriers the role of social (with financial) and environment factors is vital i.e. the innovations manifests the adoption, acceptance and usage inclusive of informed decision making and not just merely of technical superiority, advancement and complexity.

To harness this strength of active drivers operating in the market, the policymakers also must strategize to aptly design and implement focused policies which promotes higher integration of energy market encompassing social and environmental benefits. As the technology is eventually used by the end users and consumers, hence the innovative product must fulfil the technical feasibility but also must cater the socio-economic and eco-friendly behavioral aspects. Technical drivers thus do not operate indifferently in individual setting. Three of them are cause with direct influence while remaining three are effect with secondary indirect effect, but majority of them seem to have both types of influence on one another. The multi-objective optimization strategy with expansion of energy management system to different sectors, establishing communication infrastructure, energy saving, DR participation, and acceptance of energy saving technologies lot more depends upon various cause driver criteria such as robust microgrid, innovations in small scale operation yields effective outcomes and flexibility and resolving on-site deployment issues along with training/ education to locals and low emissions low cost configured technologies with proactive ecofriendly legislatures and agreements.

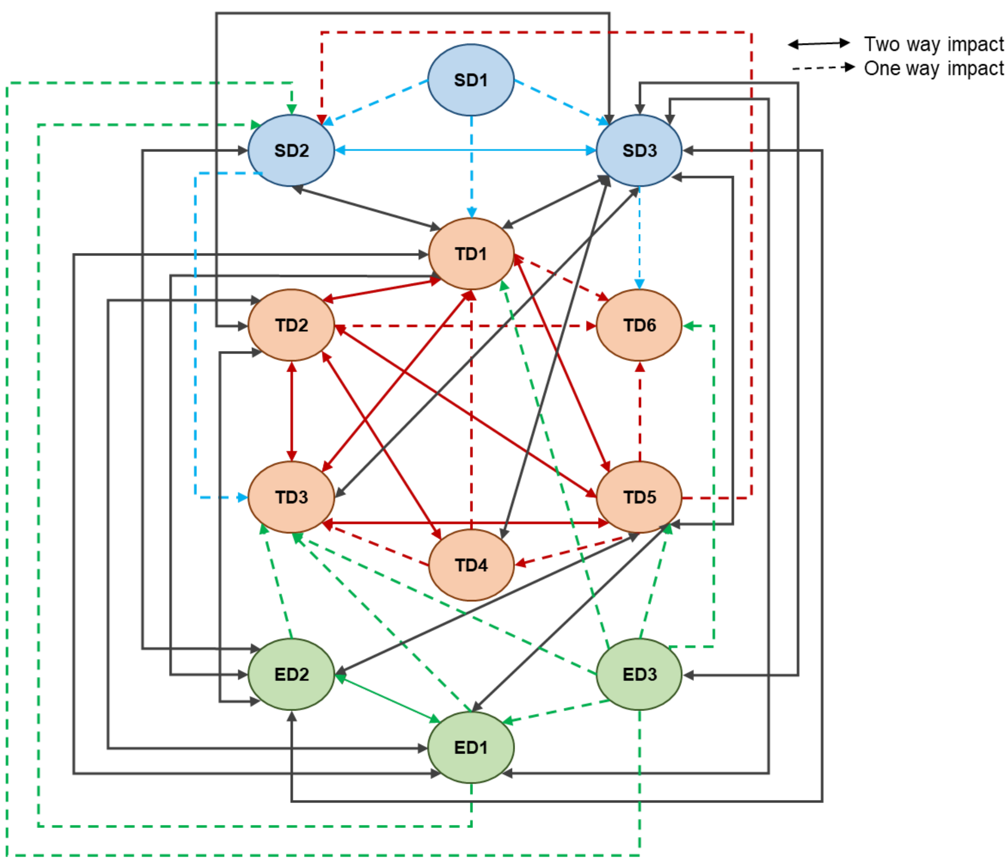

Figure 10 DEMATEL based Technical, Social and Environmental Framework Drivers: ecoTools

Here, none of the drivers is restricted and exclusive to the framework as observed in the obstacles to innovation. This framework is providing lot of insights in terms of existing intra and inter influential relation which provides mapping for better understanding drivers' scope and potentiality despite lagging regulatory framework, present obstacles, financial risks, and competitive markets. If these drivers get leveraged by full active engagement of all the involved stakeholders, then too quite a lot reduction of hindering effect of barriers can be reached.

7 BRIDGE

RE-EMPOWERED project aims to develop and demonstrate novel tools to provide a complete solution for all stages of a Microgrid/ Energy Island and Multi-Microgrid applications. The main goal of RE-EMPOWERED is to develop and demonstrate solutions for energy transition of local energy systems based on multi-energy Microgrids, interconnecting multiple energy vectors from both EU and Indian parts. For the development of the ecoTools, the obstacles to innovation must be considered and discussed, in order to map the current situation in Europe as well as India and recommend solutions for each case. The BRIDGE initiative will assist on this scope via its experience in similar issues. RE-EMPOWERED project will participate in the actions of the four Working Groups of the BRIDGE Initiative, contributing to the topics of each WG. The partners that will join the BRIDGE initiative have already been identified. Several Tasks and WPs of RE-EMPOWERED are engaged with the actions of BRIDGE and several partners will participate in the General Assemblies, presenting the status of the project and promote its outcomes. The main objective of RE-EMPOWERED is to contribute, via the ecoTools developed in this project, to the goals that the BRIDGE initiative has set through its actions.

7.1 BRIDGE General Description

BRIDGE is a cooperation group involving 90 projects, of which 58 are ongoing (latest update April 2021), in the areas of Smart Grid, Energy Storage, Islands, and Digitalization funded under the Horizon 2020 program over the last 6 years (2014-2020) [31]. Its main focus is to foster the exchange of information, experience, knowledge, and best practices among its members. BRIDGE wants to provide field experience, feedback and lessons learned from the participating projects to help overcome the barriers to innovation. It aims at gathering coordinated, balanced and coherent recommendations to strengthen the messages and maximize their impacts towards policy makers in view of removing barriers to innovation deployment.

BRIDGE Working Groups

Four cooperation groups (Working Groups) are engaged for the successful progress of this initiative, addressing cross-cutting issues enlisted as follows:

Data Management

- Communication Infrastructure, embracing the technical and non-technical aspects of the communication infrastructure needed to exchange data and the related requirements
- Cybersecurity and Data Privacy, entailing data integrity, customer privacy and protection
- Data Handling, including the framework for data exchange and related roles and responsibilities, together with the technical issues supporting the exchange of data in a secure and interoperable manner, and the data analytics techniques for data processing.

Regulation

Regulatory aspects concerning integration and harmonization aspects of market design:

- Harmonization at the level of products and services, including the role of energy communities as service provider.
- Cross-border and regional cooperation.

- Integration of market -based and non-market-based flexibility mechanisms.
- Coordinated flexibility markets for system services.

Consumer and Citizen Engagement

- Segmenting, analysis of cultural, geographical and social dimensions.
- Value systems - Understanding Consumers.
- Drivers for Engagement.
- Effectiveness of Engagement Activities.
- Identification of what triggers behavioral changes (e.g., via incentives).
- The Regulatory Innovation to Empower Consumers.

Business Models

- Defining common language and frameworks around business model description and valuation.
- Identifying and evaluating existing and new or innovative business models from the project demonstrations or use cases.

Overview of the BRIDGE projects

The stakeholders involved in BRIDGE projects are enlisted below:

- **Consumers** include residential, professional and industrial consumers, as well as cities acting as consumers in projects.
- **Regulated Operators** are TSOs and DSOs as defined by the Electricity Directive.
- **Regulators** are the National Regulatory Authorities as defined by the Electricity Directive.
- **Local Energy Communities** are defined as associations, cooperatives, partnerships, non-profit organizations or other legal entities which are effectively controlled by local shareholders or members, generally value rather than profit-driven, involved in distributed generation and in performing activities of a distribution system operator, supplier or aggregator at local level, including across borders.
- **Power technology providers** are hardware manufacturers for power transmission, distribution and generation technologies. Storage providers are considered in a separate category (all storage technologies are considered, including batteries from EVs and hot water tanks). ICT providers are software and telecommunication vendors.
- Research & Innovation stakeholders include research centers, universities, think-tanks, consultants and other services.
- **Energy Suppliers** include power generators, retailers, energy service companies (ESCOs) acting in the competitive energy market. Aggregators are market participants that combine multiple customer loads or generated electricity for sale, for purchase or auction in any organized energy market. Market operators include power exchanges, brokers and traders on the energy markets.
- **Others** is a category that covers stakeholders that do not fall in any of the above-defined categories such as international organizations, communication agencies, water supply operators, etc.

Geographical distribution of BRIDGE projects

BRIDGE projects involve stakeholders and demonstrators or pilot tests of technologies and solutions from 40 countries as presented in figures 11 and 12 [31] respectively.

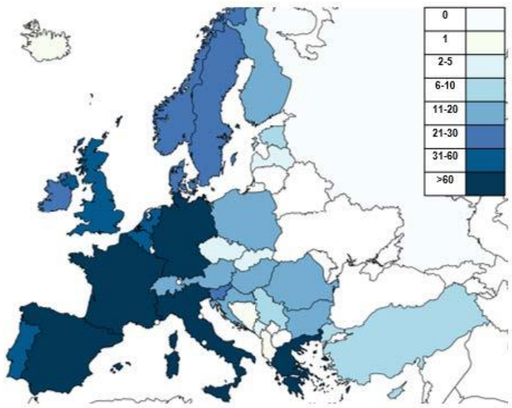

Figure 11 Number of stakeholders involved per country

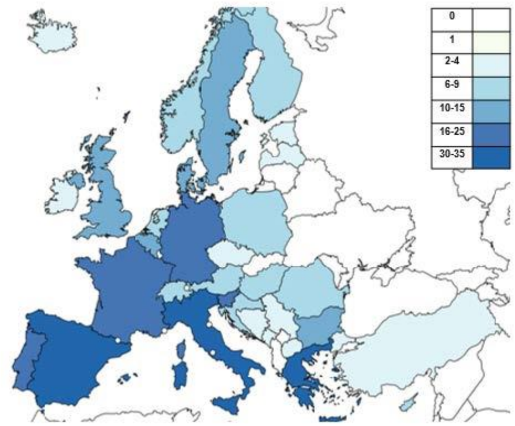

Figure 12 Number of demos or pilot sites per country

7.2 Status on the BRIDGE Projects

As mentioned earlier the BRIDGE Initiative concerns almost 90 projects, of which 58 are ongoing and 32 that are already finished. The latter involves projects that started from 2014 - 2016 and finished during 2017 - 2020. At the following table are presented the number of ongoing BRIDGE projects by HORIZON call.

HORIZON Call	Title	No of BRIDGE projects
LCE-02-2016	Demonstration of smart grid, storage and system integration technologies with increasing share of renewables: distribution system	1
LCE-05-2017	Tools and technologies for coordination and integration of the European energy system	1
LCE-04-2017	Demonstration of system integration with smart transmission grid and storage technologies with increasing share of renewables	4
LC-SC3-ES-3-2018-2020	Integrated local energy systems (Energy islands)	8
LC-SC3-ES-4-2018-2020	Decarbonizing energy systems of geographical Islands	3
LC-SC3-ES-5-2018-2020	TSO – DSO – Consumer: large-scale demonstrations of innovative grid services through demand response, storage and small-scale (res) generation	2
SU-DS04-2018-2020	Cybersecurity in the Electrical Power and Energy System (EPES): an armor against cyber and privacy attacks and data breaches	3
LC-SC3-ES-1-2019	Flexibility and retail market options for the distribution grid	8

LC-SC3-ES-2-2019	Solutions for increased regional cross-border cooperation in the transmission grid	2
LC-SC3-ES-8-2019	European Islands Facility - Unlock financing for energy transitions and supporting islands to develop investment concepts	1
DT-ICT-10-2018-19	Interoperable and smart homes and grids	1
DT-ICT-11-2019	Big data solutions for energy	4
LC-SC3-EC-3-2020	Consumer engagement and demand response	7
LC-SC3-ES-3-2018-2020	Integrated local energy systems (Energy islands)	3
LC-SC3-ES-6-2019	Research on advanced tools and technological development	2
LC-SC3-ES-10-2020	DC – AC/DC hybrid grid for a modular, resilient and high-RES share grid development	2
LC-SC3-ES-4-2018-2020	Decarbonizing energy systems of geographical Islands	5
LC-SC3-ES-5-2020	TSO-DSO cooperation	1

Table 21 Number of Ongoing BRIDGE Projects

7.3 Description of the actions of the Working Groups

7.3.1 Data Management

Exchange Reference Architecture

BRIDGE report on energy data exchange reference architecture aims at contributing to the discussion and practical steps towards truly interoperable and business process agnostic data exchange arrangements on European scale both inside energy domain and across different domains. The main outcomes derived from [32] are:

- Proposal for the definition of a common European reference architecture.
- Setting up European CIM (Common Information Model) user group and CIM repository.
- Repository of data roles and updates to HEMRM (Harmonized Electricity Market Role Model).

The high-level SGAM based reference architecture for European energy data exchange as finally proposed in this report is summarized according to Fig. 13 [32].

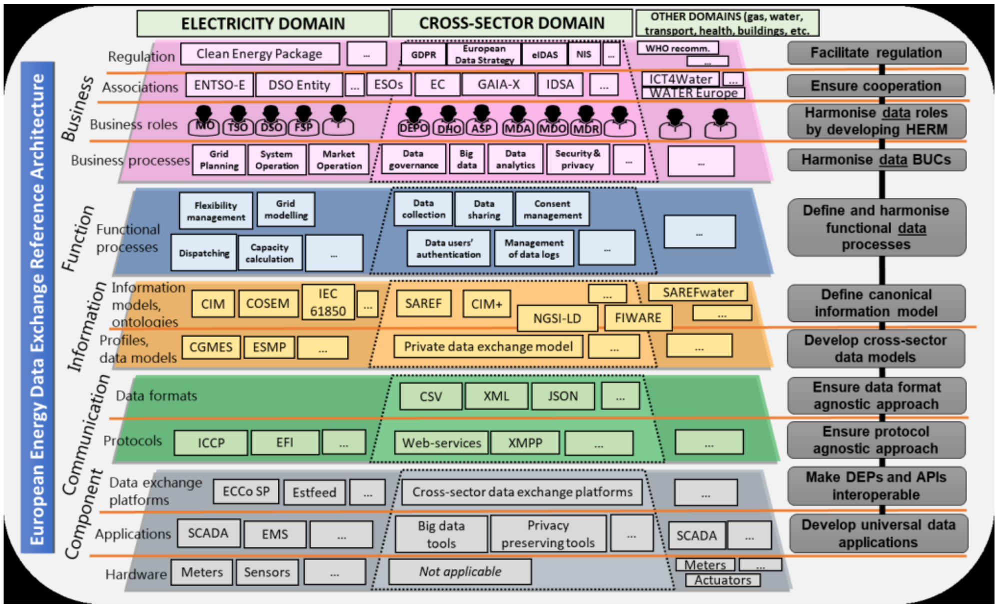

Figure 13 SGAM reference architecture [32]

Interoperability of flexibility assets

According to the objectives on the "Interoperability of flexibility assets" were presented, mainly focused on [33]:

- Enable interoperability of flexibility assets by maintaining a set of recommendations, best practices and possibly tools.
- Focus on interoperability at function layer (system use-cases, services) and information layer (semantic interoperability, data model, etc.).
- Cover the full flexibility chain, from the bidding/negotiation/activation of flexibility to the control of the flexibility assets on the field.
- Rely on inputs from the BRIDGE projects when it is it the most relevant considering their timeline, e.g. at M12 when the use-cases and the architecture are defined.
- Define and run a stable methodology that will be used during several years to build up results based on the outcomes of the past projects while also integrating the outcomes of the new projects.

According to the abovementioned objectives five outcomes were produced, as presented below:

- Methodology to study interoperability of flexibility assets.
- Reference framework to study interoperability of flexibility assets.
- Catalogue of relevant solutions/standards for each interface.
- Functions standardization.
- Gaps and extensions/modifications of solutions/standards.

Use Case repository

The BRIDGE Data Management Working Group developed a Use Case (UC) Repository [34], based on the Use-Case Methodology defined in the standard IEC 62559-2:2015 and built in a modular way. All projects have been invited to test the preliminary repository, in order to evaluate the tool and send feedback for improving it in the new versions. Based on the feedback, some identified errors were fixed and some additional functionalities were decided to be added in the next iterations, such as:

- Versioning & Revisions.
- Authoring.
- Web-based edition of UCs.
- Advanced search, combining with roles' repository and with CIM repository.

The tool will be available for all the projects of BRIDGE, after the testing procedures. The type of licenses for the use of the tool that have been suggested are:

- Creative Commons license for the use case files.
- Apache2 for the processing tools.

This will allow the redistribution and modification of written code, so that anyone can not only use it, but also adapt/improve.

7.3.2 Regulation

Harmonized Electricity Market Role Model

The Harmonized Electricity Market Role Model [35] intends to show a common view of the EU Bridge Projects about the roles (and the possible actors playing those roles) in the electricity market with focus on flexibility. The main objective is to provide a base of discussion for an update of the existing model, able to include the new roles identified by the Innovative Projects under the EU Bridge Program. The outcome of this analysis outline the needs to upgrade the ENTSO-E – ebIX – EFET HEMRM, being a base for further discussions with all the relevant stakeholders and Institutions involved in the electricity sector, for comments and further tuning and developments, to be at the end analyzed with ENTSO-E – ebIX – EFET.

Synergies between demos – ID Cards

This Action aims to initiate a common repository of information on demo sites using generic demo ID cards which were developed within this action [36]. The ID cards were designed based on discussions and experiences from the members of the Regulation WG and provide information on development of demo sites, their assets and expected outcomes. Samples of the ID cards were presented and specifications for a web repository solution were developed, in order to allow easy search through the demo sites across Europe.

7.3.3 Consumer and Citizen Engagement

For the scope of the consumer and citizen engagement Working Group (WG) [37], four main objectives were targeted, mainly focusing on:

- Building methodologies to engage consumers in the energy sector
- Building methodologies to support the constructions of organizations to involve consumers in the energy system

- Building objective assessment criteria to consumer engagement
- Building models for collective action of citizens

Topic	Conclusions	Gaps
Socio economic drivers of engagement	The subgroup focused on two main points, user groupings (inform engagement strategy building), and adaptation to COVID-19. The result of the first item was an analysis of the matrix needs / motivation / behavior for 5 grouping of consumers: (private, collective, industrial and others). On the adaptation in reaction to the COVID crisis, the group has produced a set of preliminary recommendations for project consortiums.	• Explore the adaptation of engagement strategies per consumer groupings. • Collect more collective animation techniques and their adaptability to online/ removed group work.
Group building	The group focused on the field experience of the BRIDGE projects of the ways to build consumers groups. Several practices were collected through surveys among on-going projects. This survey revealed three main phases of the Group Building process: The Starting phase, the Operating phase, and finally, the Sustainability phase. Moreover, only a few projects have established and used a methodology for group building in most of the cases.	• More group building effective and efficient methodologies to improve the quality of formation and operation of the consumer group while shortening the time needed. • Clear and improved coupling of smart grid with common interest establishing group sustainability.
Governance and organizational models	The objective of this group was to define the currently used organization models for community-based initiatives, focusing on governance principles and their implementation in energy communities, as the most advanced form of community-based initiative. The main outcome of this survey depicted the need of a legal form to guarantee a sustainable engagement of a citizen group, via a transparent, trust-worthy, and democratic governance model. Cooperative models are the most often represented to achieve this outcome.	• Explore the transferability of democratic governance principles to the non-cooperative entities. • Explore the modalities of scaling of those principles to larger organizations. Explore the impact of policy to support the development of democratically governed legal forms, allowing for citizens to engage in more collective actions.
Assessment of engagement	This sub-group explores the stages of change that a community-based project is going through its construction. Using the existing indicators and metrics, the group concluded that most of the currently used metrics are related to later stages of construction. Therefore, European projects tend to evaluate only the more mature initiatives, often	• Explore more metrics and indicators for the early stages of change, allowing for projects to better understand and assess starting community-based initiatives.

	ignoring the maturing of initiatives through the first stages.	
Smart tools	Two main conclusions derived from this sub-group. • There are already several mature tools for engagement of consumers and • There is a lack of tools that includes a user-centric approach and supporting a partnership with the consumer. Most of the BRIDGE projects tend to overwhelmingly have an approach based on volunteering which prevents from diverse and inclusive samples. This bias might damage the relevance of the tools developed and speaks for a more inclusive people centered approach to development. This also reinforced the need for an engagement strategy that will build representative samples for technological innovation.	• Exploration of more incentive structures for the tools away from individualistic incentives. • Provision of a better maintenance concept (constant feedback loop) for the smart tools created by projects More diversity of user profiles for tools

Table 22 Conclusions and Gaps from each SWG

To this end, the WG was divided into 5 subgroups, with specific topics, such as:

- Socio economic drivers of engagement
  - Collect evidence around the incentive strategies implemented by projects to ensure participation and involvement of consumers.
- Group building
  - Study the ways to mobilize consumers to act collectively and build a consumer group.
- Governance and organizational models
  - Explore governance models for collective action groups. This looks at principles that are the base for citizen participation.
- Assessment of engagement
  - Find a range of indicators and monitoring techniques to understand, monitor and assess the development of collective action groups.
- Smart tools
  - Collect an exhaustive list of tools and technologies supporting consumer participation and the ways those tools are supporting the involvement of consumers.

SWG	Findings
Regulated Activities	Within this WG, five main issues have been determined, based on the regulated grid activities raising a specific challenge: • Incentives provided to operators and market players in order to facilitate the development of a positive business case for smart equipment • Market design to meet efficiency and scalable demands • Data and financial flow-organization for the different players

	• Market design issues for the use of flexibility by the Distribution System Operator (DSO) • Local flexibility markets, the trading of flexibility and the stakeholders involved in such local markets.
Local Energy Management	This SWG analyses the scope for business models revolving around consuming self-generated electricity (prosumage) individually and collectively. To this end, several topics were examined mainly focusing on: • Individual self-consumption • Collective self-consumption • Peer-to-peer (P2P) energy trading at the DSO level • Batteries and other storage components
Energy Storage	According to this SWG the main issues arise in the area of storage were analyzed mainly focusing on: • Further involvement of ICT and technology providers • Financial incentives and regulation evolvement, encouraging RES development • Centralized batteries should not belong to regulated entities • Distortion of energy markets due to insufficient storage capacity leading to inflexible conventional power generation • Insufficient incorporation of traditional business cases • Consideration of life cycle analysis (LCA) and assessment of the socio-economic impacts • Targeting on specific Use Cases to maximize the electricity market related income of the existing assets
Demand Response	The main objective of this SWG deals with demand response on assessing business models' conditions related to a change in the power consumption for a better management of microgrids. The main issues that the survey addressed are: • Consumers' engagement • Enable a fair and open market framework for flexibility services • Revenues, costs & ROI of demand response

Table 23 Findings of BM-SWG

All the subgroups ended with some really important conclusions as well as the gaps of each scope were identified, and a plan of the next steps were prepared. Both the conclusions and gaps from each subgroup are presented in Table 22.

The WG, after completing its survey, tended to propose a list of recommendations and next steps that are concluded below:

- Formalize a targeted engagement strategy specific to each community and each user group
- Work with existing community initiatives
- Work with specific organizational structure to create consumer engagement
- Provide adapted procedures for community energy initiatives to support their specific governance needs
- Use different indicators for growing citizen-led initiatives based on their maturity

- Create people-centric solutions vs technology centric solutions
- Include more evidence-based engagement methodologies
- Move forward from Market focus to value focus

7.3.4 Business Models

For the better analysis of the business models used in BRIDGE projects [38], four sub-working groups were developed, each one focused on specific topics:

- Business Models aspects in Regulated Activities.
- Business Models for Local Energy Management.
- Business Models for Energy Storage.
- Business Models for Demand Response.

The main findings of the WG are depicted in Table 23.

In order to support the working progress of this WG, three Business Model tools have been developed:

- **Nobel Grid**: propose scenarios for the techno-economic evaluation of innovative smart grid technologies and associated business models
- **DOWEL**: Calculate Key Performance Indicators (KPIs)
- **inteGRIDy:** Help the business modelling for future cities and technologies.

8 Future Planning Provisions

Several barriers prevent end users, both individuals and groups, to make the efficient and profitable investments in energy efficiency and discourage them from adopting practices, and work - life styles, favoring energy efficiency and/or sufficiency. This low adoption of efficient technologies and sufficient practices results in the 'energy efficiency gap'. Several policies and policy packages have been adopted and implemented by governments at local, national, and regional level to avoid, overcome, or reduce the barriers. In general, most of the policies implemented around the world focus on the 'technical' efficiency of products, systems, or buildings, including changing the end user behavior towards investments in energy efficient solutions.

In India, microgrids have the potential to boost the economy by bringing electricity to remote, Tier 2 and Tier 3 regions (Classification of Indian Cities) and allowing small-medium businesses to grow. In EU they can also play a significant role in the transition towards a more sustainable and efficient energy system. As more clean energy comes in, a mix of central grid and microgrid should be looked at to fulfill the need. Fossil fuel energy generation is cheaper than microgrids, but the cost of latter is coming down quickly with time and scale is reached. In India coal enjoys more government subsidies in contrast to renewables while places an enormous burden on climate and local environment, which is unaccounted for in its cost. To conclude, for connecting all people to quality affordable power, it is important that this expansion happens with green resources towards decentralized smart energy systems and promotes local businesses without impacting the environment.

The following table summarizes the main conclusions from the analysis and the provisions, both existing and future, in policy making.

Description	Conclusions	Provisions (Existing and Future)
Energy Policy/ Regulation in India	Regulatory interventions for development of renewable energy sources are: • tariff determination • defining RPO • promoting grid connectivity • promoting market expansion MNRE created RPO compliance cell to meet solar and wind power goals RPO trajectory for 2022 and renewable energy policy is finalized in India	Regulatory authorities should formulate necessary standards and regulations for hybrid systems Additional policy measures have targeted consumer information, through a variety of campaigns, training, and media in different end use sectors Carbon pricings and energy/ carbon taxes are important policy tools to induce behaviour change depending on end-users' price elasticity Intense and trade specific technical, operational along with social sensitization of renewable

	Ministry of New and Renewable Energy (MNRE) is implementing green energy corridors to expand transmission system Amendment in tariff policy released in May 2018 by MNRE with following intentions: • inexpensive and competitive electricity rate for the consumers • attract investment and financial viability • decrease perceptions of regulatory risks through predictability, consistency, and transparency of policy measures • development in quality of supply, increased operational efficiency, and improved competition • increase production of electricity from wind, solar, biomass, and small hydro • achieve better consumer services through efficient and reliable electricity infrastructure • supply sufficient and uninterrupted electricity to every level of consumers • create adequate capacity, reserves in the production, transmission, and distribution sufficient for the reliability of supply of power to customers [39] In May 2018, MNRE announced a national wind-solar hybrid policy [39] • optimal and efficient use of transmission infrastructure and land • variability reduced in renewable power generation • supports hybridization of existing plants • tariff based transparent bidding process • battery storage for output optimization MNRE with Confederation of Indian Industry supports Skill Council for Green Jobs (SCGJ), National Occupational Standards, and Qualification Pack	technologies is required to get appropriate manpower who also act as agents of awareness for deployment of such technologies in communities' projects In-house manufacturing to be boosted to reduce the investor's risks for import of the equipment and devices. For this, fund allocation and procedural ease is provided however, slow R&D and technology transfer requires adequate attention Immediate need to formulate and implement a dedicated policy to promote islanded microgrids particularly in rural and remote areas where grid extension is not feasible to ensure last mile electricity access to the poorest and vulnerable communities. Local stakeholders' specifically from communities who have commissioned such islanded microgrids as local energy solutions to be involved during planning, execution of the policy Policy interventions to achieve micro-level needs of the consumers which are though led by technical solutions but are more socially just and sustainable fulfilling their aspirations Design Prosumer policy with suitable tariff structure, revenue stream, balance in energy demand and supply, quality of power

	Investor concerns rising due to solar import tariffs and conflicts between developers and distribution firms Lack of dedicated policy for the deployment of islanded microgrids based on renewable energy to ensure last mile electricity	
Energy Policy/ Regulation in EU	Energy efficiency and energy conservation are key component in the EU energy policies EU policies mainly focused on improving technical energy efficiency Some policies have attempted to target end users' behavior Focus to achieve carbon neutrality climate change targets for emissions and below 2°C by 2050 as per Paris Agreement EU policies fairly moderated energy demand, but more integrated policies focusing on changing consumer behavior on energy efficiency, energy conservation, and sufficiency are needed Market integration and cooperation for access to better electricity infrastructure and cost-effective solutions Additional policy measures have targeted consumer information, through a variety of campaigns, training, and media in different end use sectors	Policies to change the end users' energy consumption through energy conservation and sufficiency measures have emerged very recently such as personal carbon allowances, building carbon allowances, and energy saving feed-in-tariffs but requires thoughtful implementation New attention to effective policies for energy conservation, behavior change, and sufficiency will contribute to reach carbon neutrality by 2050 Implementation of carbon pricings and energy/ carbon taxes can be important policy tools to induce behaviour change depending on end user's price elasticity Information privacy and security are critical issues when dealing with the personal data. Cybersecurity becomes vital.
Demonstration sites in India	Sensitive to local environment conditions, asset exposure to extreme weather, and site specific concerns, land availability Remote locations causing logistical issues in transportation of equipment etc. No or low existing infrastructure	Site specific issues cannot be absolutely eliminated however resilient structures, light weight modular equipment, plug n play devices, can mitigate the risk to large extent in not only reducing physical damage but also failure/ energy outages of entire microgrid

	High fixed and variable costs Stakeholders' engagement is either very low or no methodology defined for their participation even community involvement Technology complexity and integration problems have potential to delay the deployment WTP is affected by households' ability. Occasionally low-income households wish to pay to contribute for the development of renewables but are prevented from the unaffordable available options IoT based remote data monitoring system challenging due to poor communication infrastructure Negative externalities, environmental issues, weak viability causing high risks for investments Solar is available in daytime and variable therefore requires battery storage system with replacement causing ecological concern	Mainly disaster management, minimal risk location siting, resilient structures, alarming system, preventive behavior by communities must be an integral part of such projects engaging all stakeholders across Policymakers in cooperation with educators and other agents should organize environmental education and training programs especially where citizens have expressed their unwillingness to pay or exhibited quite low WTP levels Affordable "green" tariffs or contracts to introduce, to enable low-income households for renewable energy diffusion To achieve a wider diffusion of renewables across EU, however, it is of great significance that citizen majorities will pay some premium regardless of their income status Devise energy consumption feedback to enhance citizens' WTP by providing adequate information to consumers both on the benefits of renewable energies and the available renewable electricity contracts and tariffs Information campaigns and focussed group discussions frequently among communities
Demonstration sites in EU	Sensitive to local environment conditions, resource utilization fears and site-specific concerns Low participation rate in decision making process High fixed and variable costs Environmental licensing complexity concerns due to the proximity to shoreline for the island demo sites	Ensure customers can switch energy providers without having to pay penalties or exit fees and without any disruption to their energy supply Policymakers to ensure that all relevant processes are simple, fast, non-bureaucratic, and cost-effective For energy transitions, citizens' acceptance and support to be implemented systematically in phases

	Land and infrastructure ownership issues Unwillingness to pay was negatively related to low levels of information on green electricity contracts and renewable energy whereas citizens with higher information levels were more willing to pay Integration of district heating into demand management framework is challenging Cybersecurity, data privacy, data storage and sharing issues of consumers Negative externalities, environmental issues, weak viability causing high risks for investments People hesitate to opt for renewable electricity contracts due to perceived uncertainty about the process and switching cost of energy suppliers Solar is available in daytime and variable therefore requires battery storage system with replacement causing ecological concern	Robust business modeling and establishing feasible financial options at all stakeholders' level for achieving social benefits: local employment, better health, job opportunities, life standard, and consumer choice Environmental policies/ regulations to align with cross-sector policies, add complementarity, reduce burden Proper disposal, recycling and safety methods to be adopted when dealing with hazardous elements and generate awareness among communities Develop cost effective and advanced collaborative R&D at national/ international level with market integration
ecoToolset	Load shedding is the circular debt caused by government institutions, poor revenue collection, insufficient tariff, corruption, losses, theft of electric power, and dispute on tariff Financial bottlenecks and risky investments due to associated high cost of development and long gestation periods On-site deployment issues caused due to variability, infrastructure challenges, resource acquisition and utilization, weather conditions marked with high seasonality, extreme conditions and unpredictable changes Lack of trained manpower, technical know-how, skilled locals thus increasing the	To facilitate R&D in renewable power technology, a national lab policy on testing, standardization, and certification was announced by the MNRE, India Technology Development and Innovation Policy released in October 2017 to promote research, development, and demonstration (RD&D) in the renewable energy sector to [39] • produce renewable power devices and systems domestically • evaluate standards and resources, processes, materials, components, products, services, and sub-systems carried out through RD&D

	operational risks while also impacts the technology acceptance rate by the end users on account of ignorance and behavioral usage aspects Multiple energy sources and vectors leads to integration and optimization problems which requires specific functionalities to be embedded with the use of smart technologies Many technical solutions face data privacy and cybersecurity issues further making it intense due to lack of proper legislation, digital infrastructure and targeted policies provisioning any penalty Low emissions technologies are not effectively proliferated due to less comparative advantage vis-à-vis fossil fuel or traditional energy sources despite having negative environmental effects Low level of community participation also hinders the commercialization and exploitation of such innovative technologies in the energy systems In a local energy microgrid system another issue is of interoperability which hinders the capability of equipment and software applications to exchange and make use of information and operate in conjunction with one another	• provide funds for conducting training and workshops, surveys, awareness • share expertise, information, institutional mechanisms for collaboration • efficiently support knowledge transformation into technology through well-established monitoring system for the development of renewable technology [40] Technology validation, demonstration and other innovative projects regarding renewables to receive 50% financial aid of the project cost Surya Mitra program training college graduates in installation, operations, commissioning, and management of solar panels Impacting Research Innovation and Technology (IMPRINT) program to develop engineering and technology (prototype/ process) at national scale Innovative solutions to be financed via startup support mechanisms inclusive of an investment contract with investors In July 2018, Ministry of Finance, India announced to impose a 25% safeguard duty on solar panels and modules imported from China and Malaysia for 1 year. Tax quantum to be reduced to 20% for the next 6 months and 15% subsequently

Table 24 Findings and Provisions

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10 Annexes

A. Table A The 7 Point Likert Scale

Criteria	7	6	5	4	3	2	1
Effectiveness	Very High	Moderately High	Somewhat High	Medium	Somewhat Low	Moderately Low	Very Low
Regulatory Standards	Very High	Moderately High	Somewhat High	Medium	Somewhat Low	Moderately Low	Very Low
Political Acceptability	Very High	Moderately High	Somewhat High	Medium	Somewhat Low	Moderately Low	Very Low
Implementation	Too Long	Moderately Long	Somewhat Long	Medium	Somewhat Short	Moderately Short	Too Short
Efficiency	Very High	Moderately High	Somewhat High	Medium	Somewhat Low	Moderately Low	Very Low
Cost	Very High	Moderately High	Somewhat High	Medium	Somewhat Low	Moderately Low	Very Low
Externalities	Very Good	Moderately Good	Somewhat Good	Fair	Somewhat Poor	Moderately Poor	Very Poor
Sustainability	Very Positive	Moderately Positive	Somewhat Positive	No Impact	Somewhat Negative	Moderately Negative	Very Negative
Equity	Very High	Moderately High	Somewhat High	Medium	Somewhat Low	Moderately Low	Very Low

Table A The 7 Point Likert Scale

B. Table B Expert's Responses for Obstacles to Innovation and Drivers for ecoTools

ecoTool Name	Obstacles to Innovation			Drivers		
	Technical	Social	Environmental	Technical	Social	Environmental
ecoEMS	Incorporate forecast long and short term Co-optimization with other energy vectors Diverse type and size of electric specifications (demand, peak load, generating units, assets) Connection with measuring units (SCADA or other) Differ functions per pilot site	Regulatory unsteady framework Technologies mature level per pilot site Access to adequate information regarding pilot sites	Erratic weather conditions Extreme temperatures	Multi Objective optimization strategies Expand EMS management to different sectors Increased robustness	Clear documentation of existing framework is crucial Involve the locals at the conceptual phase, to persuade them for innovative solutions Acceptance of more energy-conservation technologies	Exploitation of low-emission electricity sources Production cost minimization

[ecoMicrogrid]()	Incorporate Demand Management strategies Managing various energy conservation technologies into one project Diverse type and size of electric generating assets Diverse type of energy storage systems with different technical and economic needs Differ functions per pilot site Microgrid Cybersecurity Different energy vectors in the pilot sites	Privacy concerns of Micro-grid's inhabitants Developer accessibility to assets during deployment Technologies vary by region and pilot site Laws prohibiting or restricting specific microgrid activities Uncertainty, such as the risk that a new law will be enacted to regulate microgrids	Erratic weather conditions Differ weather conditions per pilot site Concerns regarding equipment failure in harsh environmental conditions	Multi Objective optimization strategies Increased flexibility by DR and Storage Increased robustness Expand Microgrid management to different sectors	Multicultural cooperation Increasing public mindfulness and promoting stimulus for energy saving. Acceptance of more energy-conservation technologies Crystal clear legal structure is essential Provide motivation for energy saving and DR participation	Exploitation of low-emission electricity sources Lowering greenhouse gas emissions

	Possible difficulties in the justification of the presence of different energy vectors in microgrids Transfer of equipment in the pilot sites	Willingness to participate in DR schemes Access to adequate information regarding pilot sites Multicultural cooperation				
ecoPlanning	Increasing penetration of renewable energy sources in Non interconnected islands creates operational problems in the grid Increased RES penetration necessitates bigger spinning reserves to ensure available power during generation fluctuations	Complex regulatory framework Limited funding instruments available to energy communities Top-down energy planning excludes local communities from the energy market	RES asses require landscape changes, which have to align with the locals Off-shore wind turbines cannot be exploited due to regulatory framework Components pollution, such as batteries	Multiple innovative solutions already successfully tested on similar systems High fossil fuel and emission costs compared to RES Multiple RES technologies capacity, working better together due to risk sharing	Early mutual agreements Involve the locals at the conceptual phase, to persuade them for innovative solutions Solutions that address seasonality are well received by the local community High energy costs and grid stability	Environmental legislation promotes clean energy transition and green innovation Significant air pollution by local thermal stations High environmental awareness

	Traditional thermal generators are subject to operating constraints Increasing demand/load peak needs capacity deployment High seasonality may lead to low utilization factor of infrastructure Poor regulatory framework for DSM and for EVs penetration in place in Greece		from RES with storage assets	Small scale allows innovation to produce significant results Problems with network stability and non-served load lead to studies for new generation capacity	issues make customers friendly to innovative solutions.	
ecoDR	Lack of data communication infrastructure at Indian demo sites Need of different features of smart meter for Indian and EU demo sites. (e.g. load shedding not	Acceptance of technology by the users. (such as load shedding feature)	No specific environmental obstacles.	Need to establish communication infrastructure (wired/wireless) Options to disable non-essential features as per the demo site requirements	Educate the users about the benefits of the technology	

	needed in EU sites, dynamic pricing is not applicable in Indian sites)					
ecoPlatform	The existing SCADA system covers the needs of a particular asset but not more than that Tools need to be cheap and reliable to provide information ecoPlatform as a data collection unit requires interoperability among sensors, SCADA systems, which is often not the case ecoPlatform needs to be associated with other tools to create value to the customers. This is usually difficult to identify and	No	No	System integration To be able to operate more flexibly Provide services to the power grids thereby improve business model	Increased efficiency of overall energy system	More renewables integrated with lower cost

	implement when multiple stakeholders are involved Minimum intervention to the current system possible					
ecoMonitor			During flooded conditions, water quality may get deteriorated and sample collection may not be possible			Offline parametric study will be performed immediately after flood once site is accessible Ask local people to collect water samples during flood
eco Community	Different data protection and privacy policy regulations across India and EU Security considerations with regards to exchanging sensitive information	Limited acceptance of technology Little citizen participation Language barrier: Particularly in Indian sites, where the initial	No relevant environmental obstacle	Applying both EU and India privacy regulations to the fullest, so the tool is compatible with both entities Working closely with the ecoPlatform developers to integrate the	Incentive to cut down the energy bill and increase their hours of electricity through electricity pricing Featuring mechanisms that will make their life easier, e.g. scheduling of	

		reports suggest that most energy consumers are not familiar with English		security mechanisms smoothly	communal energy uses Supporting different language packs, including local languages. Maximizing the visual content over text whenever possible Easy to understand and use graphic user interface of ecoCommunity Training and guidance material through effective multi-media for in-house and hands on training on how to operate the equipment	
ecoResilience	Resilient structure is designed based on simulated conditions but real conditions at	No specific social obstacles	PV panels may get submerged (partially/fully)	Appropriate safety factor to overcome the discrepancies resulting from real		Placing the electronics and electrical components at elevated locations

	demo site may have some variations Design of foundation depends on soil characteristics and ground water table, which continuously varies throughout the year at Ghoramara demo site		during flooded conditions	deployment scenario Design of suitable wider and deeper foundation through numerical simulation		based on available flood data

Table B Expert's Responses for Obstacles to Innovation and Drivers for ecoTools

C. Table C Primary Obstacles to Innovation for ecoTools

#	ecoTools	Technical obstacles to innovation						Social obstacles to innovation				Environmental obstacles to innovation	
		Handling diversity of assets (storage, peak,	Demand manage ment and forecasti	Demo site specific variation s,	Interoper ability issues (SCADA, sensors)	Co-optimiz ation with other	Cyberse curity issues	Data protect ion, privacy issues	Low local commu nity particip	Limited accept ance of technol ogy	Limited access to informa tion	High seasonal ity, generati on	Pollut ion issue s

		load, generation, conservation, reliability)	ng issues	functions, energy vectors, remoteness, capacity, infrastructure, equipment transfer, operating constraints		energy vectors		and complex/ non-existing policy regulation	ation in energy market	(load shedding, cost, low value)	and funding instrument	fluctuations, extreme weather conditions (temperature, wind, flooding)	
1	ecoEMS	X	X	X	X	X	X	X			X	X	
2	ecoMicrogrid	X	X	X		X	X	X	X		X	X	
3	ecoPlanning			X				X			X	X	X
4	ecoDR			X						X			
5	ecoPlatform	X		X	X	X				X			
6	ecoMonitor			X								X	
7	ecoCommunity			X			X	X	X	X			
8	ecoResilience			X								X	

Table C Primary Obstacles to Innovation for ecoTools

D. Table D Primary Drivers for ecoTools

#	ecoTools	Technical drivers						Social drivers			Environmental drivers		
		Multi-objective optimization strategy	Robustness and integration of microgrid (security, load etc.)	Expansion of energy management system to different sectors	Resolving on-site deployment issues	Innovations in small scale and flexibility yields effective outcomes	Establish communication infrastructure	Training and education of locals/ users	Acceptance of energy conservation technologies	Energy saving and DR participation	Exploiting low emission electricity sources	Low cost renewables integration for emissions reduction	Legislative structure and mutual agreements
1	ecoEMS	✓	✓	✓	✓		✓		✓		✓	✓	
2	ecoMicrogrid	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
3	ecoPlanning				✓	✓	✓		✓		✓	✓	✓
4	ecoDR				✓	✓	✓	✓					
5	ecoPlatform		✓	✓	✓	✓	✓		✓	✓		✓	

6	ecoMonitor				✓								
7	ecoCommunity	✓	✓	✓	✓		✓	✓	✓			✓	✓
8	ecoResilience				✓		✓						

Table D Primary Drivers for ecoTools