THE IMPLEMENTATION OF MULTI-ENERGY SYSTEMS: POLICY AND REGULATORY IMPLICATIONS

Sanket Puranik[1*], Iliana Ilieva[1], Farhan Farrukh[1], Mirza Haider[2]

[1]*Smart Innovation Norway, Halden, Norway*
[2]*Grenoble Institute of Technology, Grenoble, France*
**sanket.puranik@smartinnovationnorway.com*

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Abstract

Linking various energy sectors has proven to be an effective way of decarbonizing the energy system. The interconnection between different sectors allows synergies between them to be exploited, thus integrating higher amount of renewable energy. Energy systems where different energy sectors and vectors are optimally operated in combined fashion are often called local multi-energy systems (MES). However, regulations play a key role for the large-scale deployment of local MES and often decide their economic and legal feasibility. Regulations are, therefore, seen as one of the major barriers to achieve the full potential of local MES. The objective of this paper is to assess policy and regulatory environment concerning implementation of local MES in several European countries. The proposed methodology allows case-by-case assessment of regulatory impact on local MES implementation. Recommendations on regulations are also provided based upon the analysis of focus countries. Further development is needed to allow comparison between different countries, finding markets which are most supportive for local MES and providing recommendations to policy makers.

1 Introduction

Electric energy has been the core focus of political thrive and developments in CO_2 emission reductions to combat climate change. However, meeting the environmental targets as well as guaranteeing secure supply and affordable prices of energy today and in the future requires clear strategies addressing all energy vectors, and not only electricity. Especially, in the local context, utilising all existing energy vectors reveals potential for improvements in technical, economic, and environmental performance.

The most commonly addressed energy vectors are electricity, heating/cooling and gas. The recent developments around electric vehicles (EVs) have added mobility into the mix. Multi-energy systems (MES) are those where electricity, heat, cooling, transport and other energy vectors interact with each other at various levels [1]. MES can exist on different geographic scales, from country level to local level (for example loads connected to one distribution transformer). The development of local MES is answering the need for improving the overall energy efficiency and utilisation of distributed energy sources where they are produced. In broader European context this reflects the goal of achieving the challenging climate target, whereas, in a national setting, relevance to electricity grid stability in the context of local generation, increased amount of EVs and geographical challenges can be made.

In rural areas, local MES can benefit both end users and energy providers/grid operators to optimise the consumption and production in a local setting, beyond a purely electric energy supply [2] [3]. In particular, local MES could increase the security of supply under demanding climate conditions. For the purpose, different vectors could compensate each other in the local setting in case of power outages, for example through islanding mode. And even without additional challenges, the utilisation of heat vectors is particularly important for regions in the North.

However, activities around the local MES are still in early stage. Even the most promising examples of local MES implementation are still executed with public funding, and thus, dedicated to local MES policies and regulations are limited. To contribute to the MES field this paper refers to the status of existing regulations, using a specific methodology for assessment where the regulations' focus and degree of supportiveness is investigated.

To carry out the assessment, information is collected from the Horizon 2020 project E-LAND. Within the E-LAND project various tools falling under the technical, business and community building domains are being developed to support the creation of local MES. With three pilot sites in Europe (Norway, Spain and Romania), the project provides sufficient database to be used as input for the paper's analysis. In this respect, specific attention is paid on the policy and regulatory environment surrounding energy communities, which are at the core of local MES implementations.

To attend to its purpose, the rest of this paper is structured as follows: Section 2 provides the methodology where, a three-step approach for assessing the policies and regulations is provided. Next, Section 3 provides the results from assessment at the specific pilot locations. Finally, Section 4 concludes the discussion.

2. Methodology

A three-step approach is applied to reach the goal of the paper (Fig. 1). First, the attributes, which form the main characteristics of local MES at E-LAND pilot sites are identified. The second step comprises of finding and ranking areas of regulation which affect the identified attributes. Based upon this ranking, key areas to be investigated further are selected. The ranking's aim is to select regulations which have high impact on the implementation of local MES. In the third step the regulations in different countries where the E-LAND project's pilots are located are evaluated using a four-point scale (0 to 3) for local MES implementation. For ranking of regulation areas and evaluation of regulations, community members and stakeholders from the pilot sites are consulted.

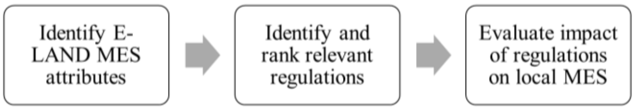

Fig. 1 A three-step approach to assess regulatory impact.

2.*1 Identification of key attributes*

An extensive list of attributes related to E-LAND pilot sites and their respective business goals has been prepared. Listing all the attributes is beyond the scope of this paper and the detailed description has been documented in [4]. To summarise, these attributes includes storage technologies (thermal, battery & hydrogen), E-LAND technical tools [5], affected stakeholders (energy communities, consumers/prosumers, and aggregators) and e-Mobility sector.

From the list of attributes three main focus areas have been defined – business, technology, and community. Relevant regulations are to be structured according to their belonging to one of those areas (Table 1). Both national and international regulations are referred to, and while the presented overview does not necessarily cover all possible regulative documentation, it is indicative of the most eminent regulations referring to the considered attributes. Brief description of the regulations' areas is to follow next.

- Business: To achieve sustainability in the long run and target monetary self-reliance of a community based MES, a clear understanding on the regulatory aspect of business is necessary.
- Technology: This regulatory domain refers to a vital element of the local MES. And while various technologies can be utilized within a MES incorporating different energy vectors, the regulations related to technology are particularly important.
- Communities: One of the salient features about the pilot sites with the E-LAND project is that they aim to function as an energy community with certain degree of self-consumption and/or generation. Therefore, the identification of regulations pertaining to energy communities is of high relevance for the successful MES establishment.

While the regulations on an EU level are often present in several sources, the following Table 1 gives examples of regulatory documentation, main points of which refer to the presented attributes.

Table 1 Regulations per focus area

Regulations' focus area	**European regulations**
Business	
Regulation for fair electricity pricing	[6]
Regulation for use of hydrogen	[7]
Regulation for new market actors such as aggregators, communities, etc.	[6]
Regulation on taxation for use of battery storage	[8]
Technology	
New technology and demand response	[6]
Regulation on standardization of battery storage	[9]
Community	
Regulation to develop and exploit local energy communities	[10]
Regulation to support communities in the financial aspect	[10]
Regulation to address energy community functioning and structure	[10]
Regulation to support self-consumption	[10]

2.2 Ranking of regulations

The relevant regulations are evaluated to determine their significance for the MES implementation and investigate the criticality of regulative support. A score from 0 to 3 is given, score of 1 is given if the regulation is not important for the attribute's function. A score of 2 is given if the regulation is slightly important for the attribute's function. A score of 3 is given if the regulation is very important for the attribute's function. 0 is given if the regulation is irrelevant for the attribute's function.

Finally, the scores are summed to indicate the overall importance for the attributes and the degree of supportiveness.

2.3 Evaluating regulations in pilot countries

The task involved here for the pilot owners was to assess the attributes against the regulation areas and evaluate regulations against their relevance to pilot site requirements and national legislations. The pilot owners assessed the impact of regulations based upon their business ambition documented in [11].

Now, the results section to follow will present in more detail the outcome from evaluating regulations associated to the different pilots within the E-LAND project. In addition, the degree of supportiveness towards the implementation of MES will be discussed.

3 Results

3.1 Harbour-based local MES (Norway)

The local MES setting for the E-LAND pilot in Norway aims to help the harbour become an energy hub, adding value to land transport, ship transport, and to the local handling and storage of goods. As part of the work carried within the E-LAND project, regulatory attributes belonging to the harbour are classified according to the core areas. Based on interviews and research carried at the harbour, the above presented attributes were classified into three categories, depending on their level of impact for the harbour as a local MES (Table 2).

Table 2 - Attributes, as seen from regulative perspective, defined according to their impact for the harbour.

High impact attributes	Consumer; Prosumer; Aggregators; Energy communities; Energy efficiency; Distributed energy resources; Energy as a service; LES optimisation; Battery storage; Hydrogen storage; Supercapacitors; EVs; Charging infrastructure; Power quality;
Moderate impact attributes	Thermal storage
Low impact attributes	Energy management system; Energy planning application; Multi-vector simulator; Enterprise service bus; Optimal scheduler; Energy forecaster; Data pre-processing application; Demand side management; Building management system;

The Norwegian Water Resource and Energy Directorate (NVE) pays attention on several of the attributes that concern the local MES implementation at the considered harbour (see Table 2). Yet, the specific national regulations to support the attributes' realisation within a local MES are somewhat limited and a look into the European regulations is in many cases necessary. Currently many of the regulations related to new market roles, flexibility, innovative services, and storage are under development and NVE is actively participating in the regulative development on both Nordic and European level. In particular, the attributes-related the topics flexibility, renewable sources in the market, beneficial end-user technology, self-consumption and energy communities are being focused upon [12].

With respect to the attributes concerning local MES and energy efficiency, regulative guidelines are given in [13]. The general energy-supply and power quality guidelines, laws and regulations for Norway are provided in the various energy-related documentation [14]. Guidelines, referring to the security of advanced metering system are given by [15]. Considering the requirements stated within the Norwegian energy laws, NVE's additional guidelines on thermal energy are presented in [16]. However, except for the national regulation concerning connection of renewable energy sources and network tariffs [17] and those associated with the EV uptake in the country [18], most existing regulations cover to a very limited extent the needs of a future energy community establishments where MES are utilized. In particular, regulations related to central for the harbour attributes, such as local MES optimisation, aggregator/prosumer roles and energy as a service are insufficiently covered by existing regulations. And, as it can be reckoned from the intensive work ongoing across regulative bodies on both national and Nordic level, the regulators struggle to catch up with the intensive developments in the energy sector (from both business and technology perspective).

3.2 Technology park as local MES (Spain)

The pilot in Spain is a technology park with multiple businesses occupying different buildings. The technology park has its own PV plant, hydrogen electrolyser and e-Mobility fleet. Based upon assessment of the pilot owner, there are no clear regulations to support harvesting of benefits from hydrogen storage in local MES. Flexibility aggregation is not currently considered in Spanish regulation and this restricts revenue optimisation for a local MES. However, there is still a limited possibility to gain benefits from MES optimisation from retailer's perspective. Also, under the current Spanish regulations it is not possible to define contractual relationship between DSO and storage owner as the latter is not defined as a market player in electricity sector. Like most of the other EU members states there is no market in place to procure flexibility services. This makes business opportunities arising from flexibility to be limited in scope. In addition, as there is an issue of double taxation concerning batteries, it becomes more effective to use batteries for self-consumption. Communities are supported through regulation but there is limit of 500 meter concerning distance between production and consumption and a cap on maximum electricity production which is set to 100 kW [19]. More details on Spanish regulations are documented in [4].

3.3 University campus as local MES (Romania)

The Romanian pilot aims at becoming living lab showcasing E-LAND based local MES tools. Key features of such lab would be interconnection between multiple building management systems and optimisation of electrical and thermal vectors. Assessment of attributes of this pilot is documented in [4] while this paper summarizes key findings. Regulations covering self-consumption, double taxation of energy from batteries, aggregation and market participation are relevant in Romanian context with respect to the implementation of local MES. Since 2020 the aggregator role has been embedded in Romanian law [20] which opens opportunity for aggregating multiple building loads and benefitting from the electricity market. In similarity to the Norwegian case, flexibility markets are in a nascent stage. Regulations concerning aspects of community and double taxation while using battery storage are currently missing. Romanian regulations were found to be least compliant with the EU directives related to renewable energy, as compared to Norway and Spain.

3.4 Recommendations

National regulations in the considered countries do follow the model of EU legislation but may vary in their approach. From the above performed analysis it can be concluded that most of the regulation areas comply with the EU legislation. The regulations covering integrated electricity market, hydrogen, battery storage and self-consumption seem to be moderately aligned, falling short of a complete agreement. However, the policy initiatives to support entry of new market actors and to ensure financial and structural support for energy communities are very limited. In Norway, as per now, energy communities will have difficulties to incorporate new roles such as that of an aggregator even though there is a provision in the EU laws. In Spain regulations for storage ownership are still not clear and as such the regulations lag behind the Norwegian ones.

When it comes to other energy vectors the regulations are not mature enough to support robust investment decisions. Concerning e-Mobility, regulations are positive but deriving benefits from energy flexibility of electric vehicles is limited as flexibility aggregation is not sufficiently supported and flexibility markets are still not widely established. Current Romanian regulations are most restrictive for implementation of local MES from business perspective. Thus, more supportive and detailed regulations as related to the MES-related attributes is seen necessary to be able to exploit all potential benefits from different energy vectors and flexibility-associated initiatives.

Current methodology allows assessment of impact of regulations on implementation of local MES on case-by-case basis. However, the possibility to compare regulations among EU member states for their supportiveness to local MES has been limited. Therefore, the methodology needs to be further developed to allow comparison between regulatory landscape of various countries.

4 Conclusion

The regulations assessed have revealed bottlenecks in implementing business models pertaining to local MES, thereby limiting the MES' benefits or even deployment. There are certain member states which currently have more favourable regulations in place for the success of local MES and thus, innovation developers can target such countries as their Go-to markets. Furthermore, recommendations are made to policy makers to mitigate regulatory challenges to MES implementation. The methodology needs to be further developed so that analysis can be expanded to other European countries for a broader evaluation, comparison of best practices and to find out member states which have most suitable regulations to implement local MES. Overall, the work carried in this paper supports the replication of local MES, and thus contributes to a more efficient utilization of energy resources.

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