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Smart Island Energy Systems

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Developing Microgrids in the EU

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List of abbreviations

ADN	Active distribution network
aFRR	automatic Frequency Restoration Reserve
ANM	Active network management
BRP	Balance responsible party
BSP	Balancing service provider
CACM GL	Capacity allocation and congestion management guideline
CDS	Closed distribution system
CEC	Citizen energy community
CER	*Comunidade de Energia Renovável*
CWOG	Customer With Own Generation
DC NC	Demand connection network code
Dcode	Distribution Code (UK)
DER	Distributed Energy Resource
DG	Distributed generation
DL	Decree-Law
DNO	Distribution network operator
DSM	Demand-side management
DSO	Distribution system operator
E&R NC	Electricity emergency and restoration network code
EB GL	Electricity balancing guideline
EGAC	*Entidade gestora do autoconsumo coletivo*
ERSE	*Entidade Reguladora dos Serviços Energéticos*
EV	Electric vehicle
FCR-D	Frequency-controlled disturbance reserve
FCR-N	Frequency-controlled normal operation reserve
FFR	Fast Frequency Reserve
FRT	Fault-ride-through
LC	Local controller
MAS	Multi-agent system
mFRR	manual Frequency Restoration Reserve
MGCC	Microgrid central controller
MS	Member State
NRA	National regulatory authority
PCC	Point of common coupling
PGF	Power-generating facility
PGM	Power-generating module
PPA	Power purchase agreement
PV	Photovoltaic
REC	Renewable energy community
RES	Renewable energy source
RfG NC	Requirements for grid connection for generators' network code
ROR	*Regulamento de Operação das Redes*
SCS	Small connected system
SIS	Small isolated system
SO GL	Electricity transmission system operation guideline
SSEN	Scottish and Southern Electricity Networks
TCMs	Terms and conditions or methodologies of implementation
TPA	Third-party access

TSO	Transmission system operator
UPAC	*Unidades de Produção para Autoconsumo*
UPP	*Unidades de Pequena Produção*
VIU	Vertically integrated undertaking
WP	Work Package

Executive summary

The overall scope of the H2020 SMILE project is to demonstrate, in real-life operational conditions, a set of both technological and non-technological solutions adapted to local circumstances targeting distribution grids to enable demand response schemes, smart grid functionalities, storage and energy system integration with the final objective of paving the way for the introduction of the tested innovative solutions in the market in the near future. To this end, three large-scale pilot projects are under implementation in three island locations: Orkneys (UK), Samsø (DK) and Madeira (PT).

This deliverable presents an in-depth study of the concept of microgrids, of their potential development under the current legal framework at EU and national level and their possible use on the SMILE islands, leveraging the SMILE technologies. Microgrids may prove to be a key element of the transition to a decarbonised energy system. Whether or not microgrids will take this (potential) role is a techno-economic question rather than a legal one. The law, however, can facilitate the development of microgrids if policy-makers envisage there is a need to introduce such a new concept in the overall energy system. This study therefore examines this concept more closely.

A literature review regarding the concept of microgrids has shown that there is no universal definition. However, three principal components can be identified:

- Microgrids are networks that can disconnect from the public grid, temporarily operate in an islanded mode and then be reconnected to the public grid,
- Microgrids use flexibility technologies (e.g., storage, demand response, etc.) to remain balanced in all situations,
- Microgrids are local and rather small-scale grids.

The literature review also revealed the importance of differentiating microgrids from other concepts such as smart grids, mini-grids, active distribution networks or energy communities. Additionally, different types of microgrids can be identified based on their size, their purpose (e.g., industrial or community) and their centralised or decentralised character. There are also different management system models for microgrids: grids operated by a vertically integrated utility (VIU) or grids operated in a free-market.

The concept of microgrids is not legally defined in EU law or in the national laws of the SMILE countries: Denmark, Portugal and the UK. However, the entry into force of the 2019 Electricity Directive facilitates the establishment of citizen energy communities (CECs) and the involvement therein of active customers. CECs may prove to be a good basis for developing microgrids, despite the absence of any provisions involving the possibility for grids to be temporary islanded. Temporary islanding must not be confused with geographical islands such as the SMILE islands.

We note that network codes probably will have a major role to play in facilitating the development of microgrids in the EU. Currently, several of these documents already touch upon islanded operation, but almost exclusively for emergency situations and in a very restrictive way. This does not reflect the idea that microgrids on a regular basis and depending on market circumstances may be disconnected from the public grid and operate temporarily in an islanded mode before being reconnected again.

There may be several reasons for developing microgrids, but economic reasons will be key to this development. In essence, microgrids may be relevant in providing various services (e.g., to system operators) by aggregating their internal flexibility resources and offer these services to third parties. Although several network codes address the rules for ancillary services (services provided to system operators in order to maintain their networks' functions, such as black-start or balancing), various recent reports have highlighted the numerous barriers that small and medium-sized actors still face regarding the provision of such services to grid operators. Currently, the network codes do not permit potential microgrids to market their flexibility potential in order to improve their economic balance and offer more services to a system that increasingly needs them due to the growth of variable renewable energy sources. At national level, the technical rules supplementing EU network codes do not solve this issue either.

Finally, this research also encompasses the SMILE islands (Orkney, Samsø and Madeira) and the use of the SMILE technologies therein, assessing their potential with regards to the development of microgrids.

Considering the above, we make the following legal recommendations with regard to the concept of microgrids.

Consider integrating microgrids into EU law

If the EU wants to introduce the concept of microgrids, it will require a legal definition. We foresee two options.

Option 1: Define microgrids in EU law.
This could be done under the term "microgrid", but a good alternative would be "temporarily islanding network". Where the first term may suggest a small-scale network permanently isolated or grid-connected, the latter avoids this confusion and directly emphasises the key capability of the grid: disconnection, temporary islanding and reconnection.

If such a concept is to be defined in EU law, it should integrate the three components mentioned above (in ascendant order of importance), i.e. (i) a microgrid forms a local and rather small-scale grid, (ii) it uses flexible technologies and (iii) it has the capacity of being temporarily islanded. The first criterion on size can be 'translated' legally by putting a cap on installed capacity or on the number of connected customers rather than on geographical extension. The second criterion entails that the law will facilitate grid operators to rely on various flexibility instruments such as storage and/or demand response mechanisms. The third criterion also needs to be 'translated' into law as a new possibility.

Option 2: Use energy communities as a proxy.
Although EU law contains various legal possibilities to provide limited groups of customers a specific status and/or treat parts of the energy system differently with regard to unbundling requirements, we find that renewable energy communities (RECs) and especially CECs could be used as a basis for further developing microgrids. Yet, in that case they need to be amended in two regards. First, by contrast to the 2019 E-Directive the law should always give CECs the opportunity to own and operate a grid, meaning that EU Member States should not in their national laws prohibit it, as Denmark has done. Secondly, the directive must facilitate that microgrids may voluntarily operate in temporarily islanded mode.

Irrespective of the option chosen, the E-Directive would need to be amended in order to define the concept of microgrids and its regulatory regime.

Requirements for a legal regime governing microgrids in the EU

It is not sufficient that microgrids are defined in the E-Directive. They also need a specific regulatory regime. In addition to amending the E-Directive, also the 2019 Electricity Regulation and the network codes need to be changed.

This legal regime must take into account three elements. First, although microgrids can be operated in a free-market and with a legally unbundled distribution system operator (DSO), we envisage that microgrids will be easier to develop in a regime based on a VIU that will take care of generation, distribution and supply. Secondly, the regime must explicitly allow microgrids to voluntarily switch to islanded mode, outside of emergency situations and subject to an agreement with the connecting network operator (in most cases a DSO). Thirdly, microgrids must be recognised as market actors that are able to provide ancillary services in the appropriate markets (e.g., balancing markets).

Network codes set the detail of the operation rules for the networks in the EU, especially at transmission level. However, they also impact the distribution level and it is imperative that these documents provide microgrids with a proper framework. The current network codes were adopted before the entry into force of the directives and regulations of the Clean Energy Package and thus need to be updated to allow new legal categories such as active customers, aggregators and energy communities to be operated in the energy system. Apart from this and in order to fulfil a key requirement of microgrids, the EU network codes must also facilitate voluntary temporary islanding. This implies a regime that enables disconnection apart from an emergency situation, operating the grid in an islanded mode and a subsequent reconnection and re-synchronisation to the grid. This implies to conciliate fault-ride-through and islanded operation.

Last but not least network codes also are relevant to ensure that microgrids can offer ancillary services to third parties, which will be an important economic incentive. The current network codes would thus need to be reassessed in order to determine whether microgrids should be considered as power generating facilities, power generating modules, defence service providers, restoration service providers, reserve-providing units, reserve-providing groups (for multi-microgrids) or balancing service providers. In addition, can these roles be combined and if so, how?

In general, it is important to maintain a holistic view of the different codes and to integrate the codes' cross-effects if and when microgrids are included.

Assessment of microgrids under national law

At the moment the concept of microgrids is not applied in the UK, Denmark and Portugal. Moreover, the current legal regimes and legislative options differ in the UK, on the one hand, and in Denmark and Portugal on the other hand. Based on our legal assessment we conclude that:

In post-Brexit **UK**, the best option for setting up 'community microgrids' is to use the 2001 Class Exemptions Order exempting generators, distributors and suppliers below certain thresholds from having a license. This will allow them, if they so wish, to own and operate a microgrid as a VIU. This approach can be combined with the principle included in the 2006 Climate Change and Sustainable Energy Act that a community energy project may benefit from advice from the government. The main unsolved issues are the possibility of temporary islanding the grid and how the microgrids could be given access to markets gathering ancillary services.

Amendments to the UK network codes will be necessary in order to achieve that microgrids can be voluntary and temporary islanded. The distribution grid connection standard (Engineering Recommendation G99) allows for a producer to switch to island mode, but only in emergency situations and after an agreement with the relevant DSO. This should be extended to non-emergency situations (of course following the rules set by the DSO to which it is connected), and the DSOs should publish the generally expected requirements for authorising such islanded operation beforehand. In addition, the UK Grid Code should provide that microgrids could be considered as small power stations and allow medium-sized generators and small power stations to offer flexibility services to system operators – including black-start services, which are currently reserved for large generators. This could possibly be done through a combination of various sites that can create and interconnect power islands in case of a black-out. Rules governing market access and product types should be simplified and streamlined, flexibility markets made more transparent and aggregation treated on equal footing with other flexibility services.

In **Denmark**, CECs could be used as a basis for developing microgrids. However, currently CECs are prohibited from owning and operating networks. The law thus needs to be amended to allow CECs to operate and voluntarily island networks.

In the technical conditions of the distribution network companies, islanding is defined but it is considered an undesirable situation, therefore requiring disconnection of the generators. This document should be amended to authorise voluntary islanding by medium generators – this is currently limited to generators above 25 MW of capacity – subject to conditions ensuring the overall balance of the electricity system. The Danish transmission system operator (TSO) should assess the possibility of lowering the minimum size requirements for some ancillary products. For example, several frequency services have reasonable size requirements (300 kW), but these are only offered on one part of Denmark (DK2, Eastern Denmark). Also, the threshold for offering black-start services is very high, but we do not recommend to lower it, given the importance of the reliability of these services, unless the TSO would have a reliable alternative via a group of coordinated microgrids (also called multi-microgrid). The provision of reserve supply for the Danish islands represents an opportunity for well-designed microgrids and could be tested through one or more pilot projects.

In **Portugal**, the REC is currently the best option for developing microgrids, at least as long as the concept of a CEC is not transposed into national law. However, the REC regime says nothing about grid management, even though there is the option in national law for RECs to construct and operate a *rede interna*. Moreover, it remains to be seen whether the transposition of the concept of CEC in Portuguese law will allow CECs to manage and own an internal grid. In any case, voluntary temporary islanding is currently not provided for in Portuguese law or any technical regulation. In case Portugal wants to develop microgrids such islanding needs to be achieved, for example, via an agreement with the connecting DSO. In addition, a few other specific barriers have to be removed: the notion of proximity to participate in a REC should be determined on the basis of published rules and not be at the discretion of the government as it currently is, the licensing requirements for generators of 30 kW installed capacity must be checked so as not to create an entry barrier, and the obligation to size the generation plants to meet consumption volumes as closely as possible, which severely limits the potential provision of flexibility services, should be removed as well.

With regards to the possibility that microgrids may offer ancillary services to system operators, access conditions are too strict for potential small and medium microgrids. For example, a minimum bid size of 4 MW is required for interruptible load services. In addition, regulation reserves are limited to pumped hydro storage, and black-start services are not mentioned in the technical rules. Therefore, the Portuguese grid codes need to be assessed and probably amended in order to facilitate that microgrids will be able to access markets for ancillary services.

At national level, the situation regarding the individual SMILE islands differs again between the UK and the EU Member States:

Develop microgrids on the SMILE islands

All three SMILE islands present great potential for the development of energy communities, or in the case of the UK, community energy projects. With regard to the development of microgrids, the situation is more nuanced. There is often potential, but there are more barriers. However, if microgrids are being developed on these islands, they could provide very relevant and necessary services to local and/or mainland grid operators.

In Orkney, it may be possible to group the flexibility offered by the SMILE technologies in one of the active network management zones and bundle it under a single license-exempt operator cumulating distribution, supply and generation. Alternatively, all isles could potentially jointly form a single microgrid if more flexible resources are integrated, such as home batteries or electric vehicles connected to smart and bidirectional chargers. As a first step towards creating a microgrid, it may be possible to create power islands for in case of outages, depending on negotiations with the local DSO: SSEN.

In Samsø, Ballen Marina can most likely be considered as an active customer. In the future, it may even be possible to establish a CEC that could include up to the entire island, aggregating all available generation, consumption and flexibility resources. However, such an energy community would not be entitled to manage the grid. As Samsø is connected to DK1 (Western Denmark bidding zone), flexibility providers can only access markets with a minimum bid size of 1 MW, which directly excludes Ballen Marina, except through aggregation. In the future, if flexible resources would be gathered at island level, the flexibility manager may potentially access the relevant markets for ancillary services. Overall, Samsø is the most advanced island to implement many of the new EU and national regimes for local, small-scale energy actors and use the flexibility activities they can offer, except for the very islanding capacity that is a key element of being a microgrid.

The situation of **Madeira** is very specific as the island has its own regulations and network code. Its regime is fairly similar to that of mainland Portugal and microgrids are not part of it. The REC status has been transposed to Madeira without major changes to the national regime and the provisions of the *rede interna* also apply to the island. Yet, the island's network code does not authorise voluntary temporary islanding. In the context of Madeira, islanding would entail that a microgrid on Madeira could be islanded from Madeira's public grid. The code needs to be amended and modify some of its existing provisions relating to grid maintenance in order to facilitate islanding following an agreement with EEM, the grid operator. The code must also be amended to authorise medium-sized generators as potential market participants in case these wish to be considered as such. In addition, markets for ancillary services should be created in Madeira and opened to small and medium-size generators to participate in the market in case they so wish. All in all, Madeira would greatly benefit from services offered by microgrids and thus to achieve the required energy transition, but paradoxically, this island is where barriers are the greatest.

1 Introduction

At the end of the 19th century, the electricity system started on a local scale at a small size and was developed to supply neighbourhoods [1]. These local grids have merged and our current modern-day society consists of an extensive and interconnected system of networks. However, the idea of microgrids is gaining traction in the 21st century, as a consequence of recent technical, environmental and social changes.

Technically, microgrids may facilitate the deployment of distributed renewable energy sources (RESs) by coping with the variability of solar photovoltaic (PV) panels and wind turbines at a local level without congesting the rest of the distribution network or even of the transportation network. Microgrids may also reinforce the reliability of the overall grid, moving from a centralised model to a more “cellular” system, where if one section of the grid fails, the others can continue operating, even if reduced to only essential appliances. This reliability aspect proves to be a necessity with each major environmental disaster caused by climate change. This was the case after hurricane Sandy hit New York City in 2012 [2], after hurricane Maria struck Puerto Rico in 2017 [3], and after an extreme winter storm caused outages in Texas in early 2021 [4]. With such dramatic events happening with increasing frequency and force, the case for microgrids is increasingly compelling. In addition, microgrids may provide more understanding of and control over the energy system by local communities. This interest from local citizens is propped up by the growing competitiveness of local solutions for generation, storage and smart consumption management. In essence, microgrids are a way of organising the rising tide of energy communities and prosumers.

In recent decades, academics have accompanied this movement by publishing about the technical and economic aspects of microgrids. However, legal research on the concept and how to translate it into legal terms has been almost non-existent. This deliverable constitutes an attempt to create the conditions for the integration of microgrids into EU and national law. Until reforms are implemented, it assesses the existing provisions that may be of use for creating and operating microgrids with as much legal certainty as possible. This deliverable is a component of the SMILE H2020 project, which is testing and deploying various smart energy technologies on three European islands: Madeira (PT), Orkney (UK) and Samsø (DK). It also follows the SMILE deliverables D7.1 on the regulation of electricity storage and D7.2 on the integration of electricity and heat supply systems [5].

This deliverable starts by answering the question: What is a microgrid? This is done through an in-depth literature review. It continues with an analysis of the key provisions in EU law that might be relevant for developing microgrids, searching for useful legal qualifications. Then it will investigate one of the key incentives to develop microgrids and that is the extent to which they could sell ancillary services. Finally, this deliverable discusses the existing and potential provisions on microgrids in three national legal frameworks, and apply the results to the cases of the SMILE islands, following the same structure as in the previous chapter. The summaries at the end of each chapter condense the reasoning and outcomes.

2 What is a microgrid?

Before starting the legal research, it is necessary to understand what microgrids are in a technical sense. Without such an understanding, it is not possible to discuss the possibilities to regulate microgrids. That is why, building on an extensive literature review, this chapter aims to reach a common technical definition of microgrids, before formulating a legal definition and laying the foundations for a legal regime.

2.1 Reaching a common technical definition

In order to reach a common technical definition, this section first identifies the main components for a universal conceptualisation of microgrids. Second, it differentiates microgrids from other notions with which they are often confused. Third, it shows that different types of microgrids actually exist within the common notion. And fourth, an important feature of microgrids is highlighted: the choice of management systems.

2.1.1 The main components for a universal definition

The general literature on microgrids agrees on and states in various occasions that there is no universal definition of this concept [6]. In some cases, authors reproduce or combine two or three existing definitions in order to highlight this situation and provide different approaches to microgrids [7].

The following paragraphs analyse the various microgrid definitions found in the literature, before presenting and studying the most commonly used definition and finally providing the main components required to qualify a microgrid.

A variety of definitions

To display the great variety of microgrid definitions used in research, a literature review was performed. Over 30 scientific articles, book chapters, policy documents and official reports were reviewed, the vast majority of which were published between 2010 and 2020. Of these works, 16 included what they clearly considered to be a definition of microgrids [8]. These 16 documents have been organised in table 1, in which each definition is analysed and its components separated and distributed within 13 columns, each representing a specific attribute or capacity characterising microgrids.

The 13 columns assess whether each definition includes electricity and/or heat, whether it forms or is part of a low or medium voltage grid, whether it represents a single entity (towards the connecting distribution grid operator), whether it contains controllable sources or loads (load is understood as energy consumption), whether it includes generation from RESs and/or conventional generation, whether it integrates storage, whether it can switch to islanded mode, whether it comprises isolated systems (not connected to the main grid at all), whether it increases reliability, whether it can provide services to the connecting distribution grid, and finally, whether it is explicitly aimed at acting at a local level. As each definition is different, it is sometimes a matter of interpretation or deduction to consider that a requirement is fulfilled. Also, it is assumed that the definitions include energy sources and loads, as, even if not mentioned, none of the other activities can be undertaken without them. It should be noted that a number of definitions mention some specific notions, but these were either too close to other notions already present in the table, such as Distributed Energy Resources (DER)[9], too general, such as consumers, customers or end users [10], or too anecdotal, such as smart buildings [11].

Attrib. / Source	Electricity	Heat	Low/medium voltage grid	Single entity	Controllable sources/loads	Generation: RES	Generation: conventional	Storage	Islanding	Isolated	Reliability	Services to distrib. grid	Local area
Lasseter (2002)	X	X		X									X
European Commission (2006)	X		X	X	X			X	X			X	
Lidula, Rajapakse (2011)	X		X					X	X		X		
Kish, Lehn (2012)	X		X						X				X
Sanz *et al.* (2014)	X		X		X			X	X				
Schwaegerl, Tao (2014)	X		X		X	X	X	X	X			X	
Soshinskaya *et al.* (2014)	X		X		X	X	X	X	X				X
Wouters (2015)	X		X	X	X			X	X				X
Meng *et al.* (2016)	X		X			X	X	X	X		X		
Rabiee *et al.* (2016)	X		X		X			X		X			
Ali *et al.* (2017)									X	X	X		
Yoldaş *et al.* (2017)	X				X	X	X	X	X		X		X

Attrib. / Source	Electricity	Heat	(Low/medium voltage) Grid	Single entity	Controllable sources/loads	Generation: RES	Generation: Conventional	Storage	Islanding	Isolated	Reliability	Services to distrib. grid	Local area
García Vera, Dufo-López, Bernal-Agustín (2019)	X		X		X	X	X	X	X		X		
Heldeweg, Lammers (2019)	X		X						X				X
Mahdavi Tabatabaei, Kabalci, Bizon (2020)	X		X						X				
Attanasio (2021)	X	X	X							X			
Total mentions (out of 16)	15	2	13	3	8	5	5	10	13	3	5	2	6

Table 1: Analysis of the attributes and characteristics of microgrids in 16 definitions. Source: the author

The results of this analysis are manifold. First, the smallest common denominator among the definitions of microgrids is: an electricity grid capable of islanding from the public grid, meaning temporarily disconnect from the public grid and operate islanded before reconnecting to it. Second, energy storage and controllable sources and loads appear in at least half of the definitions, underlining that although not compulsory, their addition to a microgrid is often deemed very useful. Indeed, these technologies allow for the balancing of supply and demand inside a grid, and the smaller the grid, the more necessary these tools are, especially if the microgrid includes high shares of variable RESs. Third, various definitions noticeably emphasise the notion of localness, as a microgrid often has a limited geographical scope. Sometimes definitions specify that a microgrid is a "small-scale" grid [12], which is therefore local by nature. Fourth, each time a definition includes the type of energy sources that can be used in a microgrid, it either explicitly mentions both RESs and conventional (or traditional) sources, or it lists some options that always include RESs and conventional sources. This shows that, although microgrids are often presented as an option to develop local 100% RES-powered grids and to raise the penetration rate of these sources in the national energy mix, definitions are actually energy source neutral. Fifth, the reliability of the electricity supply also appears in various definitions, rather logically at the same level as the type of energy source, as the motivation for microgrid development is usually either RES development, improved supply reliability or a combination of both. Sixth, the fact that the microgrid is considered a single entity for the connecting distribution grid operator does not appear much. This shows that this is either self-evident or maybe not very important in the eyes of the authors. However, this can be tied to the management choice of the microgrid and can have important legal consequences, as is shown in section 2.1.4. Seventh, the possibility of considering an isolated system to be a microgrid is equally common and certainly indicates that microgrids are in most cases considered to be interconnected grids, which can temporarily get islanded but are not permanently so. This also has important legal consequences, as explained in sections 3.1 and 3.2. Eighth, the option to provide services to the connecting distribution grid is only mentioned in two occasions, while this is actually a very important feature of modern microgrids, especially to ensure profitability or at least to recoup (part of) the realised investments (see section 3.3). Ninth, heat appears only twice, which highlights that microgrids are first and foremost about electricity. Nevertheless, as SMILE deliverable D7.2 presented [13], electricity and heat will be increasingly interlinked in the future and EU law already requires distribution system operators (DSOs) to consider using "district heating or cooling systems to provide balancing and other system services"[14].

As a final outcome of this table, this time focusing on the rows and therefore comparing the different definitions, it appears that while some definitions are very detailed and include technical elements on generation, control, storage and so on, others are much more restrictive and constructed on a few key elements. However, there is no causal relationship between the length or exhaustiveness of a definition and its quality, as a definition can be too long, too vague, too broad or too technical, especially for use in a legal framework, and vice-versa.

In a nutshell, the core elements for a definition of microgrids based on the literature review are: an islanding-capable grid, using flexible technologies to remain balanced and forming a local and rather small-scale network.

The main microgrid definition used in the literature

The main definition used in the literature comes from the Microgrid Exchange Group and has been adopted by the US Department of Energy (DoE) [15]. It reads as follows:

> [A microgrid is] a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A

microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode.

This definition covers three criteria: a group of interconnected loads and generation, clearly defined boundaries materialising through a single connection point to the main grid, and the islanding capacity (here expressed as the capacity to disconnect and reconnect from the (public) grid). According to Attanasio [16], this definition or a variant of it is often used in US regulation, such as by the state of Connecticut [17] or on the island of Puerto Rico [18]. Indeed, it is short, but it contains the essential points. Following our literature analysis above, the only element of importance that could be added is the emphasis on energy storage and controllable sources.

2.1.2 Differentiating microgrids

It is important to differentiate the category "microgrids" from other terms and concepts with which it is often conflated or confused. Indeed, microgrids must be distinguished from smart grids, mini-grids, active distribution networks (ADNs) or energy communities, to name some of these related terms and concepts stemming from international technical literature (and not necessarily referring to legally defined notions). This is an uneasy task, however, as they often overlap, as shown by the figure below.

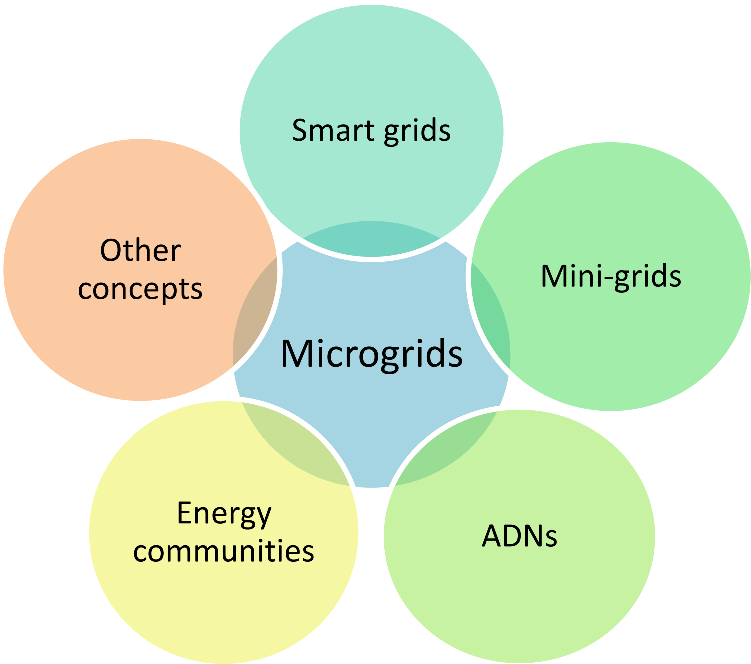

Figure 1 – Representation of the interrelationship between microgrids and other similar concepts and terms

First, a smart grid can be defined as:

> an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that assume both roles – in order to efficiently deliver sustainable, economic and secure electricity supplies. A smart grid employs innovative products and services together with intelligent monitoring, control, communication and self-healing technologies [19].

There is a close relationship between microgrids and smart grids. However, smart grids take place at a higher network level (including transmission and distribution) and on a broader geographical scale [20]. Yet, it should be noted that modern microgrids, which run entirely on variable RES (or are progressively reaching this target), need to be smart. Indeed, in order to constantly balance electricity production and demand, intelligent monitoring and control of production, storage and consumption assets is key [21]. In sum, in the future, the vast majority of microgrids will be smart grids, but not all smart grids will be microgrids.

Secondly, according to IRENA, a mini-grid is an “integrated energy infrastructure, based on distributed power-generation […]. Although normally autonomous, these can also connect to the main grid”[22]. In general, the term mini-grid is used for “remote and island communities”, especially those that are burgeoning in developing countries in order to provide electricity access in rural areas [23]. The main confusion between microgrids and mini-grids comes from the fact that (i) both systems are generally small in geographical size and installed capacity, and (ii) sometimes isolated grids are qualified as microgrids (although they are not the same). To clarify, in principle, microgrids are grid-connected but can island and reconnect at will, while mini-grids are either interconnected to the main grid or isolated from it but do not have islanding capacity.

Thirdly, an ADN is a distributed network that is able to “control a combination of distributed energy resources (generators, loads and storage). DSOs have the possibility of managing the electricity flows using a flexible network topology”[24]. To differentiate it from a microgrid, Soshinskaya argues that “fully grid-tied system[s] with distributed generation (DG) that cannot operate in island mode are not microgrids, but instead can be defined as active distribution networks”[25]. The dividing line between microgrids and ADNs thus again lies in the islanding capacity of the former, while the latter is a smartened classic distribution network.

Fourthly, microgrids may sometimes be conflated with energy communities. Energy communities are discussed more extensively in section 3.1.5, but in short, they qualify the collective organisation of small energy actors (small-size final (active) consumers, producers and/or energy storage operators), often tied together by local proximity and not driven by a financial profit purpose but rather by local environmental, social and economic improvements. Energy communities are not the material set-up of a network; instead, they constitute an entity that can own and operate such grid, which then can take the shape of a microgrid if it can island [26].

In sum, the key distinguishing features of the microgrid is its islanding capacity. This is the main quality that makes it stand out from other smart grids or small grid concepts.

2.1.3 Different types of microgrids

Once the concept “microgrid” is clearly delimited and separated from other concepts, it is necessary to identify the different types of microgrids within this category. In this regard, the literature proceeds with varying criteria. For Attanasio, “[m]icrogrids vary in size, purpose, capabilities, and the composition of loads and resources”[27]. This list covers a number of the types of microgrids, which is why below we assess the classification of microgrids based on their size, purpose, and their centralised or decentralised character.

First, many authors qualify microgrids as “small” grids, as mentioned before, in section 2.1.1. Indeed, the very name of microgrids tends to imply that these grids are small in size. However, what does size refer to in this case? Is it about geographical extension? About the number of connected customers? About the installed capacity?

Soshinskaya *et al.* argue that “there is no universally accepted minimum or maximum size” and deduce that microgrids are not defined by their size [28]. Indeed, using a geographical extension criterion would be arbitrary, especially since distances are relative between urban and rural contexts. In addition, a geographical extension criterion for microgrids would risk creating lengthy debates and would certainly legally result in one that is not adapted to the diversity of situations in EU countries. On the contrary, the same authors also wrote that the “size of a microgrid depends basically on the peak power required by the loads” and that, according to their 2014 publication, “most real-world microgrids are typically in the MW scale range”[29]. Such installed-capacity type of size criterion may be an option, given that it is already used in EU law for some cases, such as for the application of support scheme guidelines [30], of third-party access (TPA) to district heating and cooling systems for renewable energy production [31], or of the sustainability and greenhouse gas emissions saving criteria for electricity production from biomass [32].

The third use of the notion of size to be tackled is the number of connected customers. Here as well, the difference in density between urban and rural contexts may raise some difficulties. However, this criterion is already used in EU law, especially to distinguish between fewer and more than 100 000 connected customers for the applicable distribution network management regime. This can have fundamental consequences, as detailed below in section 3.1.2. However, no microgrids in the EU are expected to gather more than 100 000 connected customers each, at least for the foreseeable future, which implies that they can all benefit from the exception regime granted by this situation. Therefore, this is more of a common legal feature of microgrids rather than a criterion to differentiate between them.

Raising the question of size implies raising the question of the limit. Where to place the border between the microgrid and the public distribution grid? The literature generally considers that this limit is set at the point of common coupling (PCC) between both grids [33]. The notion of PCC compares to the point of interconnection in the EU. This is where the islanding and reconnection take place. According to Lidula and Rajapakse, the PCC “lies at the vicinity of the low voltage side of the substation transformer”[34]. But one could also imagine that a substation transformer is itself the PCC, especially if the microgrid is in the MW range. The option of creating multi-microgrids, as the literature proposes (essentially, a group of microgrids connected to the same section of the public network and which can act in a coordinated manner [35]), opens new perspectives regarding the PCC and the microgrid’s size. Indeed, what about a neural system where a full branch of the distribution grid behind a substation is composed of various microgrids that could be operated separately or together? Where is the PCC located then? At the substation itself or further down the line? How do we count the installed capacity or the number of connected customers? In these cases, the classic orders of magnitude of microgrids could be surpassed and may spur the need for different legal regimes within the microgrid category itself. In all these cases, from the existing ones to the potential future cases, one of the main legal questions to be asked is: who controls the PCC?

Secondly, it is possible to classify microgrids in five categories based on their purpose. Mahdavi Tabatabaei, Kabalci and Bizon mention commercial, community, campus, military and remote microgrids [36]. Commercial and industrial microgrids generally operate grid-connected and their purpose is to save costs and provide a backup in case of grid issues. According to the authors, community microgrids target enhanced grid stability, but we would rather consider them as microgrids created by energy communities, with the corresponding motivations, as detailed in section 3.1.5. Campus microgrids, developed by institutions such as universities and hospitals, require uninterruptible power for their research activities or medical emergencies. Military microgrids have a security purpose (e.g., avoiding power cut threats). Some of these microgrids can actually operate isolated from the public grid. However, in this case, this reopens the debate about the importance of the “grid-connected with islanding capacity” criterion and blurs the lines with other concepts. As written by Warneryd, Håkansson and Karltorp [37], some physically isolated grids have historically been labelled “microgrids”, but the use of this term in these cases should be prohibited as it only creates confusion for the legal framework to be developed. It should be noted that these different categories of microgrids are not completely relevant legally. Indeed, commercial, community and campus microgrids will most likely have the same rights and duties, and they may decide to leverage their potential differently according to their needs.

Thirdly, the technical literature often distinguishes between centralised and decentralised microgrids [38]. Indeed, microgrids need an operator in order to stay balanced and avoid black-outs. This is especially important when the microgrid is islanded (from the moment of disconnection to the reconnection and re-synchronisation with the main grid). It should be noted that the literature also sometimes refers to "fully decentralised control" versus "hierarchical control" of the microgrid [39].

In a centralised energy management system for a microgrid, the microgrid central controller (MGCC) manages the internal balancing of the system. To do so, it relies on extensive two-way communication tools, as it needs to monitor and control each unit (production, consumption or storage) in the system [40]. This type of control system is "very suitable for small scale" microgrids [41] and when such systems have a single owner [42]. It then allows for profit maximisation. However, it also has a significant weakness due to its centrality: if the MGCC fails, then the whole microgrid might collapse. It is argued to have "low reliability and redundancy"[43], it needs "more computing infrastructure [which] will result in an overload of the Microgrid central control system", and it is very difficult to implement for geographically extended large microgrids [44].

Conversely, in a decentralised energy management system for a microgrid, local controllers (LCs) are the main actors in what is called a multi-agent system (MAS). They provide their energy services (production, consumption or storage) in a competitive manner to an internal market setting [45]. Yet there is still a central controller (or MGCC), but with a more limited role, essentially negotiating with the LCs to obtain the necessary grid services and taking care of grid transactions with the connecting DSO [46]. This system's architecture is more resilient than the centralised one because it can continue "normal operation even after loss of [MGCC] functions"[47]. It is suitable for large microgrids, with many resources owned by a variety of actors [48]. The weaknesses of this system are that it requires a high level of synchronisation between the LC units and between them and the MGCC due to their interdependence [49]. Additionally, it is based on the willingness of each actor to maximise its profits, potentially creating conflicts [50].

The centralised and decentralised microgrid architectures reflect the two main models for electricity system management: the vertically integrated operator model (i.e. the pre-2000s model in the EU), which is more centralised and relies on a single actor who owns and operates the grid as well as production and supply, and the market-based model (i.e., the liberalised model such as in the EU), which is more decentralised in the sense that it includes more actors competing against each other, with in the middle an independent grid operator responsible for maintaining the grid's balance by mobilising in priority the voluntary market actors. In this sense, microgrids and their two main market models reproduce these two governance choices on a small scale. Indeed, the choice of a centralised or decentralised microgrid, based on local technical, economic, cultural and social elements, is not neutral and will have an impact on the applicable legal regime and the microgrid's actors. The following section discusses these internal architecture alternatives and their potential legal consequences.

2.1.4 Different types of microgrid management systems

Schwaegerl and Tao propose three typical setups for microgrid management systems: DSO monopoly, free-market and prosumer consortium models [51]. However, these can also be grouped under centralised and decentralised microgrids as in the previous section. The term of "DSO monopoly" corresponds to a centralised system operated by a vertically integrated undertaking (VIU). Conversely, a decentralised system tends to be operated as a liberalised, market-based system with an independent DSO. Within this decentralised system, the classic form is the free-market and the emerging one following technical developments is the prosumer consortium.

The VIU microgrid is operated by a bundled entity that may own and certainly operates the generation, distribution, supply and storage of energy. The role of the other microgrid participants (consumers, potential producers, suppliers and flexibility providers) is very limited, but consumers may be incentivised by dynamic pricing schemes. It might also be possible, to some extent, for active customers to sell flexibility services to the VIU, but this will differ per case. Legally, VIUs are prohibited in the EU, save for systems with less than 100 000 connected customers, as is discussed further in section 3.1.2. Such a VIU may be independent, or owned by another larger DSO. In that case, the question arises whether this monopoly regime applies if the microgrid's VIU is owned by an unbundled DSO, especially when the microgrid is in grid-connected mode and therefore part of the public grid. Another option is that the VIU is actually owned by an energy community. The 2019 E-Directive allows the Citizen Energy Communities (CECs) to own grids and thus potentially become small local VIUs [52]. However, this directive's provision is only optional, and Member States (MSs) may decide not to transpose it into their national law, as was decided in several MSs including France [53] and Denmark (see section 4.2.1.2).

The free-market model is essentially a small-scale reproduction of the liberalised electricity market in the EU, as described in deliverable D7.1 [54]. In this system the DSO is unbundled and cannot undertake any generation, storage or supply activities. Therefore, in case of a microgrid, there is one DSO and one or more energy producers, suppliers and storage operators. This system is usually technically run as a decentralised microgrid, with plenty of actors undertaking each activity, and still with an MGCC but with a limited role: "monitoring for system security and upper grid transactions"[55]. Such a microgrid is organised around a local energy and flexibility market where each actor tries to maximise its benefits. A free-market system could also be centralised to an extent, or a hybrid between centralised and decentralised, for example if the central actor owns the majority of the generation, storage and supply activities. This actor could be a classic private company, but it could also be a CEC.

The prosumer consortium naturally tends to be decentralised too (although it can also apply to a hybrid form of microgrid). This system relies on active customers as defined by the 2019 E-Directive or (jointly acting) renewables self-consumers as defined by the 2018 RES-Directive [56]. In this MAS, prosumers organise themselves to set their own rules for energy production, supply and storage, as well as for flexibility services that rely on demand response. Each of them owns and operates its equipment under these rules and they control the MGCC together. There is still an unbundled DSO, applying grid stability rules. This DSO has to be autonomous from the consortium (at least legally, according to EU law [57]), otherwise the microgrid becomes a prosumer-owned and -operated VIU.

Interestingly enough, Soshinskaya wrote in 2014 that for microgrids "the most common models in the EU are DSO Monopolies compared to more Free Market and Prosumer models around the world"[58]. However, this situation might have changed since then. In any case, this statement raises the question of the acceptability of a bundled grid located within an unbundled electricity market. This is one of the main recurring questions regarding microgrids according to Attanasio [59], and it justifies the need for a legal exemption for Wouters [60]. This key question of who is allowed to do what in a microgrid according to EU and EU MS law is a central theme of this deliverable.

2.2 Finding a legal definition and designing a regime

Technical and legal definitions sometimes differ. Indeed, technical definitions, albeit close to the reality, may prove too complex to be intelligible to all and to be efficiently applied by the courts. That is why a specific reflection on a legal definition for microgrids is needed. However, there is only limited literature about the legal aspects of microgrids, and the few existing publications focus largely on the lack of legal certainty for specific technical aspects, such as the connection of DERs to the grid or anti-islanding measures [61]. Some publications go further into the technical issues by requiring changes to grid codes and standards [62], showing that for such a complex topic as microgrids, modifying or adopting new laws and decrees may not suffice. There is this extra layer of very technical rules that also needs to be adapted, especially to deal with network issues (for connection and balancing mainly [63]). However, some articles adopt a broader view and raise the issue of the applicability of the existing electricity regime to microgrid actors, such as when Heldeweg and Lammers argue for a legal regime for "collective action […] to enable the factual operation of (smart) microgrids"[64].
If microgrids are to be integrated into EU law, the first decision to be made is regarding how to name them. Indeed, as section 2.1.2 shows, the key aspect of a microgrid is its temporary islanding capacity, not its size, which can vary and is never clearly stated. One option, therefore, would be to refer to such a system as a "temporarily islanding network" instead of a microgrid. This would be clearer and more in line with reality, although it would also be at odds with the term used in international literature. Once this decision has been made, the concept needs to be defined. It should arguably be based on the main elements of the technical definition. Therefore, the results from the literature review as presented in section 2.1.1 would imply that any such legal definition ensures that microgrids integrate three key components (in ascendant order of importance):

- They are local and rather small-scale networks. As seen earlier in section 2.1.3, this can be better translated for a legal purpose with a cap on installed capacity or on the number of connected customers.
- They use flexibility technologies (storage, demand response, etc.) in order to remain balanced in all situations;
- They have the capacity of being temporarily islanded (i.e., disconnect, operate in islanded mode, then reconnect and resynchronise with the public grid).

It is not strictly necessary to specify that microgrids use RESs because most technical definitions do not differentiate between energy sources, and for a small-scale system, RESs are increasingly proving to be the most adapted and cost-effective solution anyway. It is possible, although not compulsory either, to state in the definition that microgrids serve a specific purpose (e.g., to provide environmental benefits to its participants), as was done in EU law for the CECs [65].

In order to indicate to EU lawmakers an existing legal definition for microgrids already adopted in a country, we would recommend having a look at the definition adopted in California in 2018. Indeed, this is a recent one from a jurisdiction which is broadly comparable to the EU one. It reads:

> 'Microgrid' means an interconnected system of loads and energy resources, including, but not limited to, distributed energy resources, energy storage, demand response tools, or other management, forecasting, and analytical tools, appropriately sized to meet customer needs, within a clearly defined electrical boundary that can act as a single, controllable entity, and can connect to, disconnect from, or run in parallel with, larger portions of the electrical grid, or can be managed and isolated to withstand larger disturbances and maintain electrical supply to connected critical infrastructure [66].

This case provides an example of a fairly extensive definition, with a range of possible actions for the microgrid actors. It illustrates the fact that a working legal definition must also be built around key terms that are themselves defined, such as the terms “distributed energy resources” and “energy storage”. Here it becomes clear that adopting a legal definition will not automatically enable the development of microgrids. They need a regime, with adapted provisions for their actors and their rights and duties.

A legal regime for microgrids could apply the same rules as in the existing system – with the same rights and duties for network operators, electricity producers, etc. – or it can be a tailored regime with exemptions, for example regarding unbundling rules. This legal regime can define whether microgrids are to be operated via a centralised or decentralised management system, or whether both options are open. We would advise not to restrain and have the legal regime setting options, so that a microgrid can legally be run by a VIU or as a free market option (as detailed in section 2.1.4). The main element that always needs to be clarified is the system operator’s role. If VIU solutions are to be accessible, it must be possible for an integrated entity to manage energy production, distribution and supply, and thus to be exempt from unbundling rules if they exist. But the legal regime must also allow microgrid members to decide that the production and supply of energy shall not be in the hands of a VIU – a condition for the free-market model. In the latter case, a clear regime is needed for separated grid operation, cost bearing and a clear role for producers and suppliers, such as concerning their duties towards vulnerable customers. A clear regime for flexibility markets will be required as well if the microgrid is to reach profitability by selling grid services to the network operators (see section 3.2). In most cases, there is no need to create a brand-new regime as one may already exist at national or regional level, but it will usually have to be amended to some extent, given that “the introduction and operation of microgrids takes place in an already heavily regulated domain [that] comes with many systemically locked-in legal obstacles”[67].

2.3 Summary

Based on the literature review on microgrids that was conducted for this deliverable, it appears that there is no universal definition of this concept. In addition, it is important to distinguish the category “microgrids” from other terms and concepts with which it is often conflated or confused. Indeed, this often happens with smart grids, mini-grids, ADNs or energy communities, to name but a few of the related concepts. Within the category of microgrids themselves, there are different types, according to their size, their purpose and their centralised or decentralised character. There are also different management system models for microgrids: VIU and free-market models.

From this complex outset, it may be challenging to provide a legal definition, which often has to differ from a technical definition for intelligibility and enforcement purposes. However, if a legal definition for microgrids, or “temporarily islanding network” to avoid the size-induced confusion, were to be created, it should arguably be based on the main elements of the technical definitions, as identified in table 1. The results of the literature review would therefore imply that any such legal definition ensures that microgrids integrate three key components (in ascendant order of importance):

- They are local and rather small-scale networks. As seen earlier in section 2.1.3, this can be better translated for a legal purpose with a cap on installed capacity or on the number of connected customers.
- They use flexibility technologies (storage, demand response, etc.) in order to remain balanced in all situations;
- They have the capacity of being temporarily islanded (i.e., disconnect, operate in islanded mode, then reconnect and resynchronise with the public grid)

If lawmakers would rather get inspiration from an existing legal definition for microgrids in another country, it is possible to use a recent one (2018) from a jurisdiction which is broadly comparable to the EU one: the Californian definition, which is quite extensive. In all cases, it must be clear that adopting a legal definition will not automatically enable the development of microgrids. For this, microgrids do not only need a definition, but also a legal regime, with adapted provisions for its actors and their rights and duties.

3 Possibilities for microgrids under EU law

The adoption of the Clean Energy Package for All Europeans, and more specifically the 2019 E-Directive, has deepened the transformation of EU energy law with the inclusion of new actors and new activities. However, there is no regime for microgrids in EU law. Therefore, this chapter starts by analysing the existing EU legal provisions that could serve to set up microgrids with as much legal certainty as possible. Next, it assesses how the key capability of islanding can be legally recognised, including by using network codes. It also details the relevant legal framework that will economically incentivise microgrids, i.e. the provision of ancillary services by microgrids. Finally, the situation of the SMILE islands is presented and we attempt to apply the results of this microgrids-in-EU-law research to these territories.

3.1 Existing legal qualifications useful to microgrids

As explained in SMILE deliverable D7.1 of this project, the liberalisation of the internal electricity market started in the 1990s and is based on a few key principles: the right of consumers to choose their supplier, an open market for producers and suppliers, third-party access to the grid and unbundling grid operations from other (market) activities (production, supply and, more recently, storage)[68].

The previous chapter has shown that microgrids can be created when they gather three elements (in ascendant order of importance): localness combined with small size, the use of flexible resources and the capacity of the grid to be temporarily islanded. This chapter assesses how the general EU legal regime for grid management and the existing derogatory regimes comply with these requirements.

The following sections not only build upon chapter 2, but also to a large extent upon deliverable D7.1, in which the EU market liberalisation exemptions have already been presented. It should be noted that direct lines are not part of this assessment as they do not constitute a network.

3.1.1 General distribution grid operation rules

If a microgrid is part of a liberalised (free) market (see section 2.1.4), it has to be operated by an unbundled DSO. This corresponds to the general situation under EU law. Regarding DSOs specifically, article 35 of the 2019 E-Directive sets their unbundling rules. The article's main requirement is the following:

> Where the distribution system operator is part of a vertically integrated undertaking, it shall be independent at least in terms of its legal form, organisation and decision-making from other activities not relating to distribution. Those rules shall not create an obligation to separate the ownership of assets of the distribution system operator from the vertically integrated undertaking [69].

This provision means that within the existing EU legal framework a network has to be operated by a legally and functionally independent DSO. This means that although the distribution company may own grid assets, the system operator must be separated in terms of the legal form and internal organisation. In addition, according to article 56 of the 2019 E-Directive, accounting unbundling also apply to integrated undertakings "with a view to avoiding discrimination, cross-subsidisation and distortion of competition". In practice, these rules may be difficult to apply and may reduce the efficiency of the system management [70]. Although not the most obvious alternative, it is possible that part of the system operated by a DSO be treated in a different manner and operate in the free market model as a microgrid, at least if it could fulfil the three relevant criteria.

First, as regards the requirement of localness and small size, the general regime for DSOs does not include any such criteria in its provisions but if applied the option of becoming a microgrid would only apply to a (small) part of the grid of the DSO. With regard to flexibility, article 32 (1) of the 2019 E-Directive is very clear: "Member States shall provide the necessary regulatory framework to allow and provide incentives to [DSOs] to procure flexibility services". Hence, this criterion is fulfilled. Finally, the general legal regime applying to DSOs does not mention the possibility that parts of the grid can be islanded. These results are summarised in table 2 below. This table presents the three criteria and indicates whether these criteria are met. This means that a "?" indicates that the law does not so provides but there is no barrier either, a "X" indicates a negative assessment and a "✓" indicates a positive one.

Table 2: Microgrids' criteria assessment for the general DSO regime

	Local and/or small size	*Flexibility*	*Islanding*
General DSO regime	?	✓	X

3.1.2 The "less than 100 000 connected customers" exemption

Another possible option for part of the system to qualify as a microgrid, would be the exemption provided for by 2019 E-Directive as a result of which grids with a limited group of customers can be treated in a different manner. Such an exemption from the general DSO unbundling regime is included in article 35 (4) of the E-Directive and allows MSs to "decide not to apply paragraphs 1, 2 and 3 to integrated electricity undertakings which serve less than 100 000 connected customers, or serving small isolated systems". Consequently, for integrated undertakings serving less than 100 000 connected customers, legal and functional unbundling may simply not apply, thus allowing for a truly integrated entity that owns and operates production, distribution and supply simultaneously – a VIU.

When considering the microgrid criteria, it can be concluded that due to the "less than 100 000 connected customers" rule, the small size requirement is fulfilled. The flexibility provision applicable to DSOs following the general regime as mentioned in section 3.1.1 also applies here, therefore fulfilling the corresponding criteria. However, the islanding one is not fulfilled as there is nothing about it in the exemption regime.

Table 3: Microgrids' criteria assessment for the "less than 100 000 connected customers" regime

	Local and/or small size	*Flexibility*	*Islanding*
Less than 100 000 connected customers	✓	✓	X

3.1.3 Isolated systems

Isolated systems may also be exempted from the general unbundling rules. The definitions and regimes for isolated systems in the 2019 E-Directive were assessed quite thoroughly in D7.1 on pp. 11-12. For the sake of completeness, the following paragraphs provide the main applicable provisions and their interpretations, after which they assess how to use them to develop microgrids.

Starting with the definitions, the 2019 E-Directive provides for two types of isolated systems: a small isolated system (SIS) and a small connected system (SCS). Article 2 (42) states that SIS refers to "any system that had consumption of less than 3 000 GWh in the year 1996, where less than 5 % of annual consumption is obtained through interconnection with other systems". Article 2 (43) considers an SCS as "any system that had consumption of less than 3 000 GWh in the year 1996, where more than 5 % of annual consumption is obtained through interconnection with other systems".

Both isolated systems are based on the same characteristics in terms of size and year: a consumption of less than 3 000 GWh in the year 1996. However, an SIS imports less than 5% of its annual consumption, while an SCS imports more, without a ceiling being mentioned.

Considering the definition of microgrids established in chapter 2, it becomes clear that microgrids and isolated systems as understood by the 2019 E-Directive do not fully align. Firstly, the case of a non-interconnected SIS corresponds to a 100% isolated system, which is different from a microgrid (a small grid connected to the public network with temporary islanding capacities) and must therefore be excluded. Secondly, the case of an interconnected SIS – importing between 0.1 and 5% – corresponds to a quasi-autonomous system that would import very little electricity. Although it probably has the necessary flexible technologies to maintain its balance most of the time, it does not mean that it can undertake islanding as we understand in this deliverable. Thirdly, the SCS allows for more than 5% of the electricity consumed to be transported via the interconnection. With this option, too, there are different situations, from the microgrid that would, for example, be dependent for 5 to 10% of its annual electricity consumption, to the one that would be dependent for 50% of it. None of these systems is explicitly authorised to switch to islanded mode.

Overall, the legal qualification as an isolated system is full of barriers. Applying the microgrids' criteria, both SCS and interconnected SIS can be considered as local and small size network – it is part of their definition. The flexibility provisions that apply to DSOs also apply to SCS while interconnected SIS may get an exemption (although in reality it will be difficult to obtain from the European Commission). However, islanding is not legally recognised as part of their activities.

Table 4: Microgrids' criteria assessment for isolated systems

	Local and/or small size	*Flexibility*	*Islanding*
SCS	✓	✓	X
Interconnected SIS	✓	?	X

3.1.4 Closed distribution systems

The origin and the EU legal regime for Closed Distribution Systems (CDSs) were described in D7.1, on pp. 10-11. Nevertheless, below we will analyse how CDSs could be of use to develop microgrids, starting with article 38 of the 2019 E-Directive.

> Member States may provide for regulatory authorities or other competent authorities to classify a system which distributes electricity within a geographically confined industrial, commercial or shared services site and does not […] supply household customers, as a closed distribution system if:
>
> a) for specific technical or safety reasons, the operations or the production process of the users of that system are integrated; or
>
> b) that system distributes electricity primarily to the owner or operator of the system or their related undertakings.

This specific regime is not mandatorily transposed in the national law of MSs. This is only optional, as shown by the use of the verb “may” and needs to recognised on a case-by-case basis by the national regulatory authority (NRA) or another competent authority. However, if applied it remains to be seen whether a CDS could become a microgrid. First, the notion of a “geographically confined” site seems to correspond to the idea of localness and small size as is required for a microgrid. Indeed, it conveys the idea of a well-defined grid, with a limited connection to the public network but without having to be isolated. Moreover, the article explicitly focuses on industrial, commercial or shared services site to be considered as a CDS, and it explicitly excludes “supply [to] household customers”. In case it would become a microgrid, it would most likely be considered an industrial or commercial microgrid (see the types of microgrids in section 2.1.3).
Secondly, as regards the issue of flexibility, a CDS may directly use its own equipment for flexibility to cover energy losses and non-frequency ancillary service needs, instead of having to procure these services through “transparent, non-discriminatory and market-based procedures”. To do so, it can directly develop, own, operate and manage energy storage facilities or recharging points for electric vehicles (EVs), which is in principle prohibited by articles 36 (1) and 33 (2) of the 2019 E-Directive. Third, nothing is provided for CDS to operate in islanded mode.

Applying the results of this analysis to the microgrids’ criteria, it appears that CDS fulfil the local and small size requirement. They also are legally encouraged or at least authorised to directly use flexibility resources or to procure it. However, islanding is not part of CDSs’ regime.

Table 5: Microgrids’ criteria assessment for CDSs

	Local and/or small size	*Flexibility*	*Islanding*
CDS	✓	✓	X

3.1.5 Energy communities

The last exemption regime presented here is also the most recent one integrated into EU law. It was already described in D7.1 on pp. 12-14. Nevertheless, the following paragraphs will provide the definitions of energy communities before discussing how this regime may be relevant for developing microgrids.

3.1.5.1 Definitions

Among the new actors introduced by the 2019 E-Directive and the 2018 RES-Directive, there are two types of energy communities: CECs and renewable energy communities (RECs). In addition, we also present two other new actors that facilitate direct and collective energy actions by citizens: jointly acting active customers and jointly acting renewables self-consumers.

The definitions of a CEC in article 2 (11) of the 2019 E-Directive and a REC in article 2 (16) of the 2018 RES Directive are to a large extent similar although some important differences also can be noted. Both have in common the requirement that the energy community requires the establishment of a legal entity, which is based on open and voluntary participation and is effectively controlled by its members or shareholders. The latter can consist of natural persons, local authorities, including municipalities, and small enterprises (for CECs) or SMEs (for RECs). Both communities have as a primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits.

A major difference between both communities is their source of generation. Whereas a REC would be limited to renewable energy (and not only electricity) production, the E-Directive does not provide any restrictions and supports any type of generation in a CEC, not limited to renewable energy production (but always in the form of electricity). In addition, a CEC may engage in distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders. CECs may thus potentially own and operate their own grid. While the RES-Directive entitles the RECs to undertake almost all these activities too, it does not provide for a possible management of distribution grids. The RES-Directive also requires some localness as it requires that the shareholders or members of the legal entity are located in the proximity of the renewable energy projects that are owned and developed by that legal entity.

When developing a microgrid, two other new actors might be of interest: active customers and RES self-consumers. Article 2 (8) of the 2019 E-Directive reads:

> 'active customer' means a final customer, or a group of jointly acting final customers, who consumes or stores electricity generated within its premises located within confined boundaries or, where permitted by a Member State, within other premises, or who sells self-generated electricity or participates in flexibility or energy efficiency schemes, provided that those activities do not constitute its primary commercial or professional activity;

Active customers will constitute very valuable, almost essential components of a microgrid as they will be connected to this grid and will be able to offer their flexibility resources to the grid. However, when such active customers cooperate they will become jointly acting active customers or self-consumers as defined by articles 2 (14) and 2 (15) of the 2018 RES-Directive:

> (14): 'renewables self-consumer' means a final customer operating within its premises located within confined boundaries or, where permitted by a Member State, within other premises, who generates renewable electricity for its own consumption, and who may store or sell self-generated renewable electricity, provided that, for a non-household renewables self-consumer, those activities do not constitute its primary commercial or professional activity;
> (15): 'jointly acting renewables self-consumers' means a group of at least two jointly acting renewables self-consumers in accordance with point (14) who are located in the same building or multi-apartment block;

Such a group of jointly acting active customers or self-consumers could potentially also be considered as forming a microgrid, especially when its members are located on adjacent premises that together constitute a sort of bubble within confined boundaries. These confined boundaries can be interpreted as the microgrid's perimeter, with a connection point to the public grid: the PCC. Now, either the cables behind the PCC are the active customers' property (i.e., the behind-the-meter grid), or the PCC is located on the local public grid itself, which means the group of active customers has to work with the DSO to organise the self-consumption and even the islanding capacity. The first option may apply to very small communities and cables, in the same building or group of adjacent buildings, and is very close to the situation at Ballen Marina on the SMILE island of Samsø (see section 3.4.2). The second option may apply to larger communities relying on peer-to-peer trading and possibly being part of an energy community, but it will be difficult to develop islanding capacity in grid sections pertaining to the connecting DSO.
Once defined and interpreted, energy communities need an in-depth analysis with regard to their microgrids-compatibility.

3.1.5.2 Energy communities' regime for microgrids

The above has shown that a CEC, REC or both combined could be used as basis for microgrids if they fulfil the three identified criteria: localness and small size, use of flexibility and islanding capacity.

A local and rather small grid

The notions of localness and proximity are part of the energy communities' definitions. Indeed, the definitions of both CECs and RECs emphasise the primary purpose being "to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates". The REC's definition goes further by requesting that the "shareholders or members […] are located in the proximity of the renewable energy projects that are owned and developed by that legal entity". However, neither of the regimes set clear criteria relating to localness (i.e., no geographical extension boundaries) or size (e.g., in terms of installed capacity, extension, or the number of members). Regarding these notions of localness and proximity, Hannoset, Peeters and Tuerk warn against the risk of confusion between the two for the process of transposition at national level [71]. Vanhove argues that the E-Directive and RES-Directive's provisions regarding energy communities and self-consumption often use varying and undefined notions when it comes to proximity and also stresses the importance of the EU MS transposition in shaping these notions [72].

To conclude, CECs and RECs tend to be considered as rather small to medium-sized organisations that are geographically limited in scope (although less for CEC than REC) and with a rather limited energy generation capacity. Hence, CECs and RECs comply with this criterion for creating microgrids.

Use of flexible technologies

The CEC's definition, as provided in 3.1.5.1, explicitly allows it to "engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders". The REC regime as provided in article 22 (2) (a) of the RES Directive makes it possible to "produce, consume, store and sell renewable energy, including through renewables power purchase agreements". In both cases, the energy community can "access all suitable energy markets both directly or through aggregation in a non-discriminatory manner"[73]. These provisions therefore provide legal certainty that energy communities are fully free to engage in these flexibility activities. Hence, we consider that energy communities fulfil the second criteria of the legal definition of microgrids.

Islanding capacity

Although energy communities under EU law may be able to operate and manage their own 'internal' grid, there are no clear provisions that facilitate temporary islanding. This criteria is therefore not fulfilled.

Table 6: Microgrids' criteria assessment for energy communities

	Local and/or small size	*Flexibility*	*Islanding*
CECs and RECs	✓	✓	X

3.1.6 The missing piece: islanding

It results from the previous sections that neither of the existing legal regimes – neither in the 2019 E-Directive nor in the 2018 RES-Directive – fulfil all criteria for being qualified as a microgrid. Although in general the criteria of localness and flexible sources are being met none allows to temporarily island these grids. Such islanding may be desired as it allows the microgrid participants to ensure security of supply and to enable them to offer to system operators (the connecting DSO, but also a TSO) ancillary services, e.g. through load-shedding (the action of disconnecting a load to re-establish the network's balance, voluntarily or imposed by the system operator).

As noted, the possibility to develop a microgrid, and in particular to temporarily disconnect a system from the public distribution grid, is not recognised in the above-mentioned European directives. So far article 2 (49) of 2019 E-Directive touches upon this possibility as it defines non-frequency ancillary services as 'a service used by a [TSO] or [DSO] for steady state voltage control, fast reactive current injections, inertia for local grid stability, short-circuit current, black start capability and island operation capability'. These include black-start capability and island operation capability, without further explaining what these activities are. However, apart from this it is possible that provisions facilitating such islanding are, directly or indirectly, provided for in the 2019 E-Regulation and the existing network codes.

3.2 Islanding in EU network codes

The process of islanding can be separated in three phases: disconnection from the public grid, islanded operation and reconnection (with re-synchronisation) to the public grid. In addition, one must look for black-start, which is the capability to reenergise a network from scratch after a black-out. Hence, microgrids need to have an internal black-start capacity so that they can ensure that their network can run in islanded mode for as long as necessary, even if it faces internal black-outs, e.g. at the moment of disconnection from the public grid. In addition, microgrids may also be able to offer black-start services to public grid operators (especially to the TSO) but this then counts as an ancillary service and as an economic incentive to operate a microgrid (see further section 3.3 below). Therefore, the key terms to be looked for in EU law when it comes to islanding are not only 'disconnection', 'islanded operation' and 'reconnection' but also black-start facilities as these enable the microgrid to operate in both grid-connected and islanded mode. Consequently, a microgrid operator has to be entitled to set its own rules when it comes to internal black-start. Such activity is currently already recognised in the existing network codes, but it needs to be assessed whether these provisions are sufficient for microgrids and/or need to be amended in order to incentivise manufacturers to produce black-start-ready assets for this particular kind of grid. Below we will discuss whether and if so how these are dealt with in the EU network codes.

Electricity network codes and guidelines – often collectively referred to as "network codes" or "grid codes" – set a common technical framework for grids and market operations in the EU. The first generation of network codes was developed to implement the third energy package and in particular Regulation 714/2009 on conditions for access to the network for cross-border exchanges in electricity. Between 2015 and 2017, a total of eight network codes and guidelines – four of each – were adopted and "categorised into three types – network connection rules, system operation rules and market rules"[74], as shown in figure 2 below.

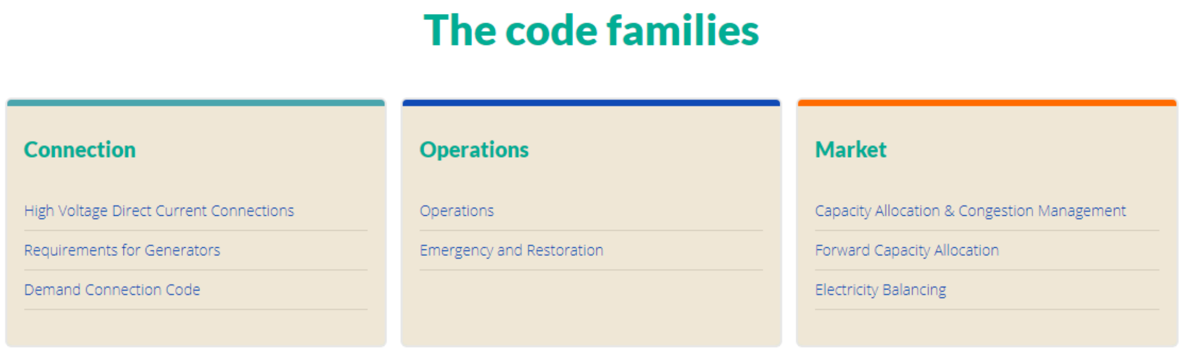

Figure 2 – The three categories of network codes. Screenshot from ENTSO-E's website, 10 Feb. 2021 <https://www.entsoe.eu/network_codes/>

All of these network codes and guidelines have been adopted as EU regulations, and are therefore legally binding, directly applicable, and enforceable in the MSs once they have entered into force [75]. However, their nature – either network code or guideline – influences their elaboration and even more so their transposition. Network codes are usually more detailed than guidelines. Indeed, although "many choices must be made when implementing the network codes nationally"[76], guidelines "are to be implemented through more than 100 regional or European TCMs [(terms and conditions or methodologies of implementation)]"[77]. Moreover, all network codes include the possibility for derogations to be provided by NRAs under certain conditions.

Network codes are directed towards TSOs but they sometimes also apply, directly or indirectly, to DSOs. Out of the eight codes, three seem relevant to microgrids' islanding capacity:

- the requirements for grid connection for generators' network code (RfG NC)
- the demand connection network code (DC NC)
- the electricity emergency and restoration network code (E&R NC)

These three selected network codes will be reviewed below on the basis of how they relate to the possibility of islanding grids and thus the development of microgrids. Firstly, their important definitions and thresholds are presented, before to detail the rules applicable to the three islanding phases.

3.2.1 Important definitions and thresholds

The three identified network codes contain a few important definitions and various thresholds that need to be presented in order to understand how the islanding rules impact potential microgrids.

Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection for generators [2016] OJ L112 (RfG NC)

The RfG NC is the network code governing grid connection rules for generators. Article 2 provides a definition of 'island operation' (para 43) and 'black-start capability' (para 45).

> Island operation means the independent operation of a whole network or part of a network that is isolated after being disconnected from the interconnected system, having at least one power-generating module or HVDC system supplying power to this network and controlling the frequency and voltage.
>
> Black start capability means the capability of recovery of a power-generating module from a total shutdown through a dedicated auxiliary power source without any electrical energy supply external to the power-generating facility.

Both definitions refer to power-generating modules (PGMs). In essence, a PGM is an electricity generation unit (synchronous, e.g. a gas turbine, or asynchronous and then qualified as a power park module)[78]. PGMs are organised into four types, in ascending order from A to D, based on the voltage of their connection point and their capacity [79]. The capacity thresholds of all the types are presented in a simplified table below – each presenting a synchronous area. These thresholds can be lowered by the relevant TSO. It should be noted that any PGM connected to a 110 kV or above cable is automatically considered as a type D.

Table 7: Thresholds for PGMs, per synchronous area. Simplified version of [80].

Synchronous areas	Type A PGM threshold	Type B PGM threshold	Type C PGM threshold	Type D PGM threshold
Continental Europe	0,8 kW	1 MW	50 MW	75 MW
Great Britain	0,8 kW	1 MW	50 MW	75 MW
Nordic	0,8 kW	1,5 MW	10 MW	30 MW

Most likely, (community) microgrids would include type A PGMs and potentially some type B PGMs into their mix. If microgrids are themselves considered as PGMs, then they would most likely pertain to types A and B, with some occasional cases of types C or D, probably for industrial microgrids.

In addition, the microgrid itself could be considered as a power-generating facility (PGF). A PGF is referred to in the definition of black start and is defined as "a facility that converts primary energy into electrical energy and which consists of one or more power-generating modules connected to a network at one or more connection points"[81]. Such a facility can be owned by a natural or legal entity [82].

To conclude, generation units inside a microgrid can be considered as PGMs but microgrids themselves may be considered as PGMs or PGFs. In both cases, the microgrid needs to adhere to the corresponding requirements (e.g., frequency range before disconnection, fault-ride-through capability, etc.), as provided for in title 2 of the code.

Commission Regulation (EU) 2016/1388 of 17 August 2016 establishing a network code on demand connection [2016] OJ L223 (DC NC)

This network code sets the rules for the connection of various systems to the public grid, including distribution systems and closed distribution systems. These terms are reminiscent of the options from the 2019 E-Directive as analysed in section 3.1 and they are either not defined or are a copy of the 2019 E-Directive [83]. The network code also defines demand-facilities, the main actors in this document, which essentially are loads connected to the distribution or transmission grid [84]. However, distribution systems cannot be demand facilities, therefore excluding microgrids. In addition, the DC NC defines 'low frequency demand disconnection' and 'low voltage demand disconnection' as load-shedding procedures decided by the system operator to preserve the network [85].

Commission Regulation (EU) 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration [2017] OJ L 312 (E&R NC)

The E&R NC aims to set harmonised rules for emergency situations. It provides various definitions that are of interest to microgrids. First, it defines 'resynchronisation' as "synchronising and connecting again two synchronised regions at the resynchronisation point"[86]. This is referring to a situation where two TSOs need to resynchronise their grids, given the reference to regions. If microgrids will be introduced, this definition should be broadened and refer to networks instead of regions, so that it can also apply to smaller systems, such as microgrids. Second, it defines 're-energisation' as "reconnecting generation and load to energise the parts of the system that have been disconnected"[87]. This situation corresponds to the post-black-out procedure, starting from the black-start service to the full restoration of the network. Third, the E&R NC defines a defence service provider as "a legal entity with a legal or contractual obligation to provide a service contributing to one or several measures of the system defence plan"[88]. A restoration service provider is the same, with reference to the restoration plan [89]. What being a defence or restoration service provider entails is to be specified in TCMs elaborated between the TSOs and the NRAs [90], but in essence a defence service can permit to avoid any black-out and a restoration service aims to re-establish normal system functioning after a black-out. Restoration starts with black-start.

All these definitions and thresholds will now be used in the following developments with regards to the three phases of islanding in the EU network codes.

3.2.2 Rules applicable to islanding phases

As explained earlier, islanding can be divided in three phases: disconnection for the public grid, islanded operation and reconnection and resynchronisation.

Disconnection

The principle in network codes is that PGMs do not disconnect from the public grid. This is indicated for type A PGMs and above [91]. Type B PGMs and above in addition have to comply with fault-ride-through (FRT) capability requirements [92]. FRT "means the capability of electrical devices to be able to remain connected to the network and operate through periods of low voltage at the connection point […]"[93]. Kish and Lehn already flagged this as an important aspect for microgrids [94], given that it impedes disconnection and therefore islanding. Therefore, clarity is needed on how to reconcile the two elements, especially as "one of the most important requirements described regarding robustness [of PGMs] is the [FRT] capability"[95].

If a potential microgrid is simply considered as a distribution system, then articles 12 (1) and 13 (1) of the DC NC require that this distribution system be capable of remaining connected to the network and to operate at set frequency and voltage ranges. These provisions directly conflict with a microgrid's voluntary disconnection in order to start islanding. If the potential microgrid can be considered as a CDS, then it is required to "have the withstand capability to not disconnect from the system due to the rate-of-change-of-frequency"[96], which again conflicts with a possible disconnection. This code deals a lot with disconnection (and reconnection) but more specifically concerning distribution systems directly connected to the transmission grid while most microgrids are expected to be distribution systems connected to other distribution systems, apart maybe for some large industrial facilities.

When the E&R NC refers to disconnection, it involves arbitrarily decided disconnection by the system operator (especially the TSO) in order to preserve the system when endangered. For instance, as part of the system defence plan, the TSO must be ready to activate low frequency demand disconnection as defined in the DC NC [97]. This code does not seem to place an emphasis on voluntary disconnection by PGMs, which would be helpful to potential microgrids.

Islanded operation

As explained previously, the RfG NC conceives islanded operation as the operation of a part of the network with at least one running PGM after disconnection. However, the regime for this islanded operation is only provided for type C and D PGMs [98]. Given that microgrids will typically contain or be considered as type A or B PGMs or as PGFs of the same size, the provisions dealing with island operation should be extended to type A and B PGMs as an option in order to allow for microgrids to integrate the technical requirements and benefit from legal certainty.

During the islanded operation mode, a microgrid might have to use black-start internally (if the microgrid itself suffers from a black-out). The RfG NC defines black-start capability but applies this option to type C and D PGMs only [99]. These rules should also be extended to smaller PGMs in order to incentivise manufacturers of PGMS to include such black-start function in the design of smaller PGMS that will be connected to a microgrid.

Island operation and black start capabilities are important features in the E&R NC, especially for identifying potential restoration service providers [100]. Yet, the E&R NC only applies to PGMs of types C and D and, under certain conditions, type B [101]. This makes it more difficult for potential microgrids to be considered as potential restoration service providers, which they could provide if acting in group, as a multi-microgrid system.

Reconnection and resynchronisation

If the provisions for voluntary disconnection and islanded operation are not microgrid-friendly, one cannot expect the opposite for the last step of the islanding process. In the RfG NC, reconnection and resynchronisation are considered as the steps following a fault [102], therefore excluding voluntary islanding and reconnection. In the DC NC, as mentioned earlier, reconnection appears a lot, but not for actors that would act as microgrids.

3.2.3 What is needed for voluntary islanding?

In conclusion, based on the three network codes reviewed, it appears that disconnection, islanded operation and reconnection are considered in all three. However, these activities are perceived as undesirable and taking place after a fault of the system or the PGM. In order to achieve voluntary islanding, we present the following scenarios. First, voluntary islanding should be facilitated and not be restricted to a post-black-out situation. This implies the need to, for example, introduce exemptions to the FRT requirements. Secondly, the current codes only provide technical requirements for islanded operation and black-start for type C and D PGMs. As most microgrids would involve type A and B PGMs, this threshold should be lowered. Moreover, microgrids could enjoy this opportunity, alone but also via multi-microgrids. Thirdly, potential microgrids need clarity about the exact roles they can have. Indeed, microgrids could be considered as PGMs, PGFs, defence service providers or restoration service providers. Nevertheless, many uncertainties remain regarding the possible combinations of these roles. These issues create barriers when developing microgrids and network codes should be modified.

3.3 Microgrids’ participation to flexibility markets

In the above we have discussed the concept and definition of microgrids. Fulfilling these criteria is not sufficient to develop such grids. There is also a need for economic incentives, as will be discussed below.

As a rule, microgrids will play a role in transition towards a decarbonised energy system by aggregating their internal flexibility to offer services and thus mitigating the variability of wind and solar photovoltaic energy. By doing so, they can recoup their investments faster and improve their business case. It is assumed that providing an enhanced business case for microgrids operators by harnessing their flexibility resources to provide services to third parties will allow the microgrids to develop more widely in the EU.

Schwaegerl and Tao list the ancillary services microgrids can provide to system operators according to their operation mode: grid-connected (normal operation) or islanded (emergency operation) [103]. In grid-connected mode, microgrids can offer frequency control support [104], voltage control support, congestion management, reduction of grid losses, or improvement of power quality (e.g., voltage dips, flickers, compensation of harmonics). In islanded mode, microgrids can provide black-start or grid-forming services to TSOs. Microgrids can therefore provide most of the demand-side flexibility services shown in figure 3, and more. Please note that this figure only refers to services provided in normal operation mode, excluding a state of emergency, when a blackout is looming or has already happened. As this figure also shows, these services are either provided to system operators (TSOs and/or DSOs) or to balance responsible parties (BRPs). In this section, we will focus on services provided to system operators in order to help maintain their network running: ancillary services (as defined in article 2 (48) of the 2019 E-Directive). In chapter 4, we will focus on these as well, but also sometimes refer to services offered to other parties, under the more general term of flexibility services.

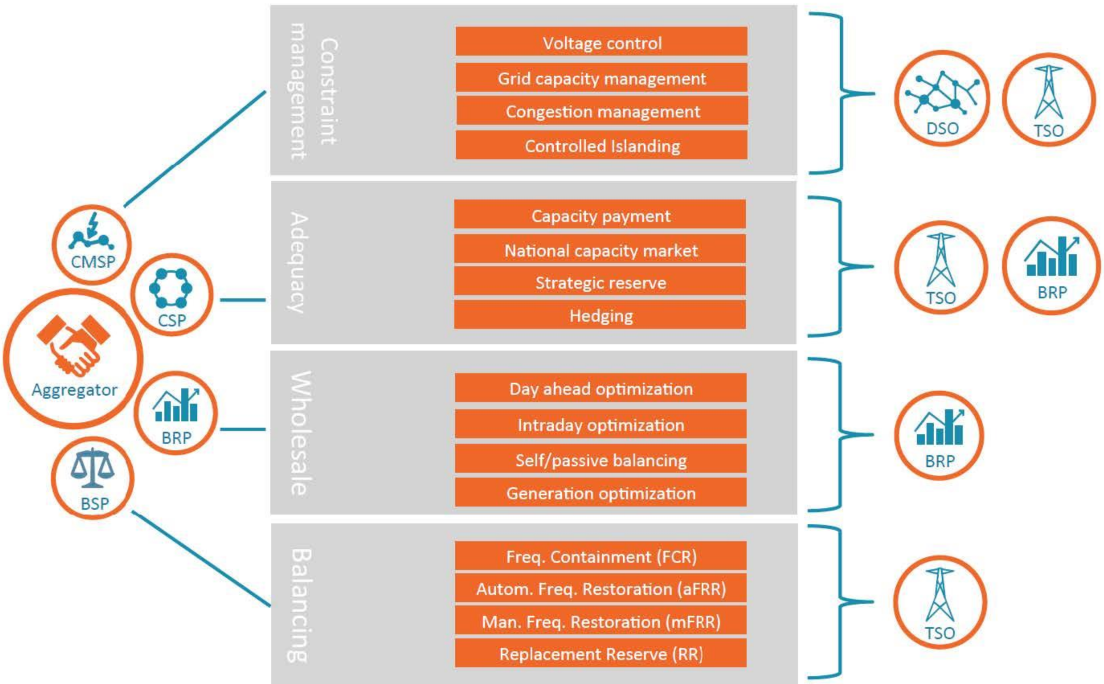

Figure 3 – Organised markets and products accessible for demand-side flexibility [105]

For Claeys, the "key success factors for delivering grid benefits include having a large and diverse portfolio of customers to help balance the grid or members from a geographically focused area to support the local distribution network"[106]. As was shown earlier in section 2.1, microgrids do offer geographically concentrated production and demand and they can also, depending on their setup, provide large or at least diversified profiles. Microgrids should therefore represent a prime opportunity for the provision of local ancillary services and be ensured of a positive business model. However, a recent study has shown that "[a]ncillary services markets are less developed than energy markets" due to the fact that their procurement "is frequently not market-based or some services are imposed to network users and hence not remunerated"[107]. If more actors will be able to provide more ancillary services, TSOs and DSOs will have more choice in terms of location, quality and price. At the same time, this will create potential revenue streams for flexibility providers, including microgrids. According to T&D Europe, this is a necessity, as "[t]he EU needs to further develop fully functional and operational flexibility markets, […] to enable the developments of business models for microgrids"[108].

The two following sub-sections will analyse the EU legislation – 2019 E-Directive and E-Regulation as well as network codes – that apply to the sale of ancillary services and assess how this may affect microgrids.

3.3.1 The 2019 Electricity Directive and Regulation

With the adoption of the Clean Energy Package and especially the 2019 E-Directive and E-Regulation, the legal regime for the provision of flexibility services to system operators by new small-scale actors has significantly improved.

As discussed earlier, the 2019 E-Directive has introduced new actors, such as independent aggregators [109], active customers [110] and CECs [111]. All three are considered market participants [112]. According to article 2 (9) E-Directive, electricity markets not only encompass the classic commodity markets but also other markets for, inter alia, the trading of flexibility. Market participants are allowed to participate in these different markets.

Two types of flexibility activities have been introduced into the 2019 E-Directive. First, 'aggregation' is defined in article 2 (18) and its regime is set in article 13. The essential part of this provision reads as follows:

> Member States shall ensure that all customers are free to purchase and sell electricity services, including aggregation, other than supply, independently from their electricity supply contract and from an electricity undertaking of their choice [113].

Secondly, articles 2 (20) and 17 define and set the regime for demand response (through aggregation for article 17). In this case, the central provision reads:

> Member States shall allow and foster participation of demand response through aggregation. Member States shall allow final customers, including those offering demand response through aggregation, to participate alongside producers in a non-discriminatory manner in all electricity markets [114].

It follows from these provisions that the aggregation of demand response must be open to all market participants, including the new ones mentioned above. However, merely authorising these new actors to provide these services is not sufficient. System operators must be incentivised to use them. For TSOs, this is not new, as they were already in charge of ensuring the system's balance under the previous regime, including through the procurement of congestion and balancing services [115]. However, so far the role of DSOs was significantly more limited. Now, article 32 (1) of the 2019 E-Directive requires DSOs "to procure flexibility services, including congestion management in their areas, in order to improve efficiencies in the operation and development of the distribution system". This procurement process must be open to "providers of distributed generation, demand response or energy storage". Once implemented, this provision will create a sizeable market for local flexibility services.

Apart from this, the 2019 E-Regulation provides some technical definitions relevant for flexibility markets, such as congestion [116], balancing [117], balancing energy [118], balancing capacity [119], and redispatching [120]. It pays special attention to the need for access of "all market participants, individually or through aggregation, including for electricity generated from variable renewable energy sources, demand response and energy storage"[121]. With regard to the concept of balancing, article 5 (1) of the Regulation makes clear that "[a]ll market participants shall be responsible for the imbalances they cause in the system". Indeed, they are either BRPs themselves or they must delegate this role to another BRP. If BRPs do not meet the production or consumption profile they have submitted to the system operator (TSO), the BRP will be financially responsible and the latter will need to rely on the balancing market to even out supply and demand (see also article 6 of the regulation). On this market, balancing service providers (BSPs) offer their balancing capacity to TSOs.

These balancing provisions are relevant when developing microgrids. Microgrids would be responsible for the reliability of their own production and consumption commitments and could potentially sell ancillary services to their connecting DSO and even potentially balancing services to the TSO. If a multi-microgrid system is developed and connected to the same transformer station, this system could potentially also provide aggregated services. As microgrids have the special ability to switch to islanded mode, they could also be remunerated for being load-shed if the system operator needs to reduce demand, and, in some cases, might be able to provide black-start services to the TSO.

Below we will assess in more detail how network codes implement the provisions of the 2019 E-Directive on "non-frequency ancillary services"[122] and article 32 of the 2019 E-Directive, which mandates DSOs to procure flexibility services [123]. Both elements are essential for the development of flexibility services and the potential profitability of microgrids.

3.3.2 Relevant network codes

This section will assess five network codes that may be relevant for microgrids that are interested in selling ancillary services to system operators with a focus on remunerated islanding (a demand-response service), remunerated black-start service and balancing services. These codes are:

- the requirements for grid connection for generators' network code (RfG NC)
- the demand connection network code (DC NC)
- the electricity emergency and restoration network code (E&R NC)
- the electricity transmission system operation guideline (SO GL)
- the electricity balancing guideline (EB GL)

Remunerated islanding and black-start services

Three network codes provide conditions that may apply to the sale of islanding as a service (part of the demand-response services then) and to black-start services: RfG NC, DC NC and E&R NC. These codes have already been presented in sections 3.2.1 and 3.2.2. First, the RfG NC and E&R NC provisions regarding island operation and black-start are relevant for the sale of flexibility services by potential microgrids. However, these network codes do not provide clarity about which markets correspond to these services (frequency services? Non-frequency services?). Aside from this, the same conclusions apply as earlier: type C PGM provisions about island operation and black-start capability should be extended to lower PGM levels, as an option. Secondly, the DC NC is also relevant for incentivising potential microgrids because this network code provides the conditions for demand aggregation and demand response services, which could be offered by a microgrid. However, currently only a CDS or a demand facility are entitled to provide these services [124]. The issue is that the CDS is not the most relevant legal qualification that could be used as a basis for microgrids, as shown in section 3.1.4, and that a distribution system cannot be considered as a demand facility as mentioned in section 3.2.1. Yet, microgrids are in essence distribution systems. In case microgrids will be developed, the DC NC should be revised in order for microgrids to be allowed, under specific conditions if necessary, to aggregate demand and provide demand response services.

Balancing services

Two network codes provide the rules for the balancing market: the SO GL and the EB GL.

The SO GL applies to various actors presented in the RfG NC and DC NC: PGMs of types B, C, and D PGMs, demand facilities and CDSs [125]. It defines grid services in the frequency domain: frequency containment reserves [126], frequency restoration reserves [127] and replacement reserves [128]. Therefore, it is of interest to microgrids that are willing to offer balancing services. Schittekatte, Reif and Meeus clearly explain the balancing system and its frequency containment, restoration and reserves products [129], and the SMILE deliverable D7.4 also explains this in more detail. The SO GL defines reserve providers as the legal entities with a legal or contractual obligation to supply the aforementioned frequency services [130]. To do so, reserve providers use reserve-providing units, which consist of a single or an aggregation of PGMs and/or demand units connected to a common connection point that fulfils the requirements to provide these frequency services [131]. If PGMs, demand units and/or reserve-providing units themselves are aggregated and connected to more than one connection point, they can be considered as a reserve-providing group [132]. Given these definitions, microgrids could potentially be considered as reserve-providing units due to their aggregation of production and demand behind the PCC. Correspondingly, the microgrid operator could be considered as a reserve provider. Multi-microgrids could also be considered as a reserve-providing group. In addition, the SO GL defines another important actor: the reserve-connecting DSO. According to article 2 (149), this is the “DSO responsible for the distribution network to which a reserve providing unit or reserve providing group, providing reserves to a TSO, is connected”. Although frequency services are to be procured by TSOs (see article 108 (2)), the transiting DSO, which is located in between the microgrid’s PCC and the transmission grid, has to be involved in the prequalification process for the reserve units or groups and may set limits to the activation of reserves located in its distribution system, therefore acquiring a sort of veto right [133].

The EB GL may be crucial for microgrids aiming to sell ancillary services to external grid operators (and thus incentive the development of microgrids) as it, in conjunction with the SO GL, provides the main rules of the balancing market. The guideline defines balancing [134], balancing services [135], and more importantly, BRPs and BSPs. A BRP is a market participant (or its representative) that is responsible for its imbalances [136]. Microgrids would certainly be considered as BRPs too, although this role potentially entails severe consequences for a microgrid that would create imbalances. A BSP is “a market participant with reserve-providing units or reserve-providing groups able to provide balancing services to TSOs”[137]. This description refers to the reserve-providing units from the SO GL and could thus also be relevant when developing microgrids. In addition, one of the guideline’s aims appears to be facilitating the participation of demand response, including aggregation and energy storage, as well as RESs in general [138]. This should favour microgrids that rely on these technologies and activities.

However, there are two potential barriers for microgrids in the EB GL to access the balancing market: (i) prequalifications and (ii) TCMs. According to article 16 (1), a BSP “shall qualify for providing bids for balancing energy or balancing capacity which are activated or procured by the connecting TSO”. As the European Smart Grids Task Force argues, prequalification “constitutes an additional process for market parties to follow and could lead to limitation of bids: the process should be clarified, and limitations applied to bids should be justified"[139]. In addition, articles 18 (4) and (5) refer to the TCMs for the activities of BSPs. Among the nine EB-related TCMs validated by ACER (the European agency of NRAs)[140] and therefore applicable across the EU (i.e., including Denmark and Portugal), five set the rules for the provision of balancing services [141]. Theoretically, microgrids can provide various balancing services [142]. Yet, the rules specified for the standard balancing products to control the frequency can prove challenging for microgrids. Indeed, from the end of 2021, the minimum bid quantity is set at 1 MW [143], which may therefore force small microgrids to be part of an aggregator portfolio if they want to sell frequency services. In addition to the 1 MW minimum size, TCMs also set the validity, delivery and activation time requirements of the bids. Potential microgrids will need to be aware of such technical requirements to design their flexibility installations accordingly if they wish to provide such services.

Facilitating the provision of ancillary services by microgrids

In sum, it seems that microgrids can provide many services as defined in the network codes, including to TSOs. However, the five network codes here reviewed need to be thoroughly checked and amended in order to allow ancillary services to be offered by potential microgrids to external parties. Indeed, current legal barriers reduce the range of activities in which microgrids can engage, do not provide them with suitable technical rules and diminish the value they can offer to external system operators for maintaining network stability at the best cost. It also remains unclear to what extent microgrids can be considered as reserve providers or reserve-providing groups, in addition to the other roles already raised in section 3.2.3. Setting clear, transparent and facilitative rules for microgrids to offer remunerated services to TSOs and DSOs can certainly be key to incentivise their development.

The existing network codes will have to be updated in order to integrate new roles and activities enacted by the 2019 E-Directive and E-Regulation. Article 59 (3) of this regulation states that the European Commission is to define a list of priorities every three years, identifying the areas to be included in the development of network codes. In October 2020, the Commission established such a list and decided to focus on cybersecurity and demand-side flexibility [144]. Both areas are of interest to the development of microgrids.

3.4 The application of EU law for microgrid development on the SMILE islands

This section aims to compare the aforementioned EU law developments to the SMILE islands demonstrators. It outlines the relevant elements of the energy situation, the application of the EU law concepts and the potential for creating microgrids and participating in the flexibility markets for Orkney, Samsø and Madeira. It builds upon the SMILE deliverables of Work Packages (WP) 2, 3, 4, 5 and 8, as well as the legal analyses in D7.1.

3.4.1 Orkney

Overview of the island's system

The Orkney islands, off the northern Scottish coast, gather a total installed electricity capacity of 62 MW, with a winter peak demand of 34 MW [145]. Most of the generation capacity is variable, with 50 MW from wind and 1.4 MW from solar PV [146]. There are also a 10.5 MW natural gas-fed turbine and 15 MW back-up diesel generators [147]. Orkney is connected to mainland Scotland by two 33 kV submarine cables with an approximate total capacity of 40 MW [148], which are primarily used to provide power to the islands. Given the combined limited capacity of the main submarine cables, of the cables interlinking the isles together and of the local generation assets, an active network management (ANM) system was set up in 2009, dividing the island grid network in zones and using "real-time automated controls to manage generation output while taking into account the export capacity at key bottlenecks within the local distribution grid"[149]. The figure depicting the ANM system is reproduced below.

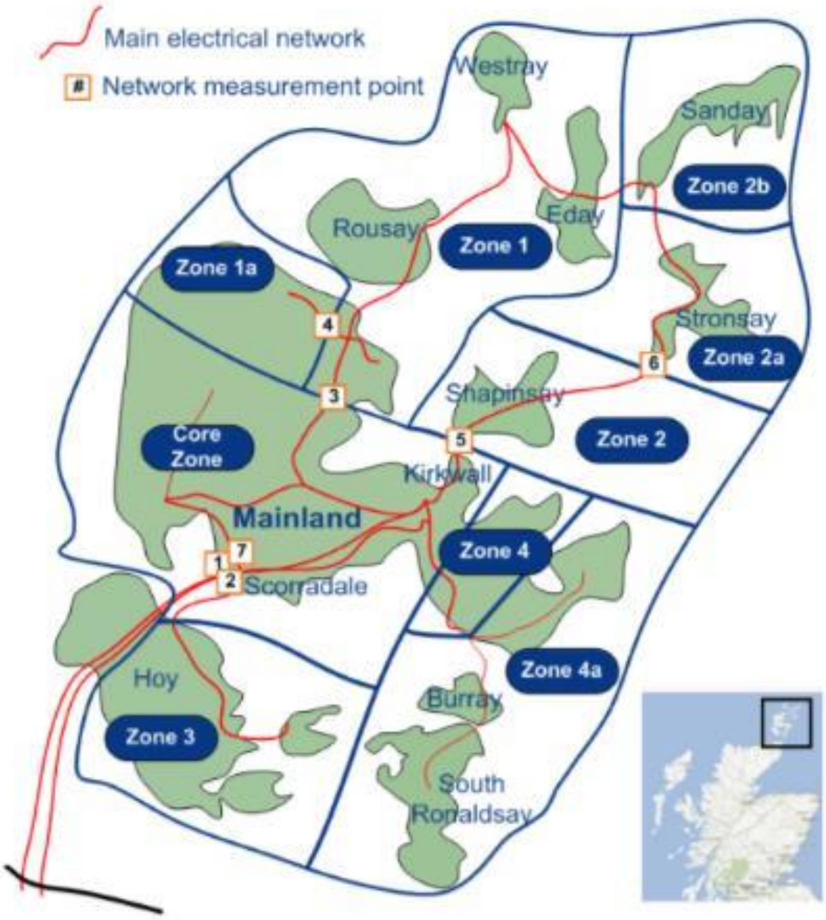

Figure 4 – SSEN's diagram of the ANM zones and island grid network [150]

Despite this system, the DNO (Scottish and Southern Electricity Networks (SSEN)) did not allow new generation connections above 3.7 kW per phase between 2012 and September 2020. In addition, local-inhabitants owned wind turbines are reaching curtailment levels of up to 80% in some cases [151].

EU law concepts

Regarding the application of EU law concepts and the possible derogations, the case of the UK is a peculiar one due to Brexit. In short, the Clean Energy Package – and therefore the 2019 E-Directive and E-Regulation did not have to be transposed in UK law. Despite the UK leaving the EU, on the short term the UK's regime is expected to be quite similar to the EU regime due to decades of legal harmonisation, similar energy system issues and the fact that manufacturers will probably push for harmonised technical requirements on both sides of the channel. The detailed national legal framework is studied in section 4.1 below, and will show that the EU regime and categories are generally relevant to Orkney, except the most recent additions. Therefore, and as explained in deliverable D7.1 on energy storage

[152], Orkney may potentially be granted some derogations based on the status of the small isolated or small connected system (SIS or SCS respectively), but the requirements are very stringent. No specific locations were identified for CDSs [153]. However, Orkney seems to represent a fertile ground for local collective ownership initiatives, given the presence of SMILE partner Community Energy Scotland (CES) and the past and present involvement of local communities in setting up and managing wind turbines. If such initiatives would develop, they could potentially, depending on the relevant national legal regime, manage a part of the grid and create a microgrid. In that case, they could also apply for the derogations for the less than 100 000 connected customers regime (that had to be transposed years before Brexit) as detailed in section 3.1.2, since the isles account for a total population of approximately 21 000 inhabitants [154].

Potential use of the SMILE technologies for setting up microgrids

As figure 4 shows, Orkney's grid is already divided into ANM zones which integrate measurement instruments at their junction points to assess and, to an extent, manage internal grid congestions. The SMILE technologies are being installed in zone 1 of the grid to bundle the newly acquired flexibility and to "maximise the impact on curtailed generation", especially from Rousay's wind turbine [155]. Within this zone, approximately 450 kW of controllable demand from households and EV smart charging is being installed [156], to which 340 kW of controllable load from the Heat Smart Orkney project can be added [157]. In total, Orkney's zone 1 can already manage around 800 kW of controllable load from a diverse set of appliances with different profiles (e.g., reactivity, costs and so on) [158]. In the future, more smart appliances can be integrated, such as washing machines, freezers, dishwashers, and so on, thus increasing the demand flexibility, knowing that part of the infrastructure (such as the gateway) can be used in this perspective [159]. However, the overall system of the islands and the technologies installed on Orkney are not designed to disconnect, operate in islanded mode, reconnect and re-synchronise with the public network. And another disclaimer, the total controllable load capacity of 800 kW is at best theoretical in the sense that technical limitations (e.g., not using a battery to its full capacity to reduce degradation) and availability conditions (e.g., for EVs, available when connected and charged enough) apply.

Participating in the flexibility markets

At present, the available flexibility provided by the SMILE technologies on Orkney has to be used in order to reduce wind turbine curtailment; therefore, there is not much economic interest in islanding a grid section as the main business model relies on consuming and exporting as much electricity as possible when it is present. However, in the future, "other commercial arrangements with the generators or DSOs could be agreed"[160]. Indeed, a vast array of demand response services could be provided by the energy producers and users of zone 1. If sufficient flexibility is available, they may be able to limit curtailments and provide frequency regulation services or voltage support at the same time, for example. Organising this zone around collective local ownership would allow such activities to be aggregated. If, in the future, there is an interest in providing voluntary-islanding-related services, then the grid metering points could serve as PCCs. Theoretically, the entire grid of Orkney could even become a large-scale microgrid (and thus could be islanded). Becoming a microgrid could also shield Orkney against the risk of submarine cable failure, and by bundling over 60 MW of variable production, 25 MW of dispatchable thermal generation for back-up and an increasing reservoir of demand flexibility, it may be able to provide ancillary services (including black-start and grid-forming capability) to its connecting DSO as well as the TSO located on mainland Scotland.

3.4.2 Samsø

Overview of the island's system

Although Samsø is the smallest of the three SMILE islands, with a population of 3 700 [161], it is a Danish powerhouse. Its total installed generation capacity reaches 35.7 MW, the vast majority of which comes from wind power, complemented by 1.3 MW of solar PV [162], for a peak demand estimated at 4.5 MW in winter and 1.7 MW in summer [163]. Of this electricity, 70% is exported to mainland Denmark through a pair of 60 kV submarine cables with a total capacity of 40 MW. Another cable connects the island to the mainland, but this one is only used for back-up [164]. In addition, 30% of the island's heat demand is covered by four district heating plants burning biomass from local resources [165]. There are currently no curtailment issues, but "there are bottlenecks which present opportunities for better management of locally generated energy"[166].

Samsø is implementing the SMILE technologies in the Ballen Marina. The project aims at reducing the electricity offtake from the public grid by installing a system that maximises self-consumption of renewable energy. This system involves solar PV panels, a battery, various heat pumps in the connected buildings and smartening the demand coming from the boats and the buildings [167]. Once this project is successfully implemented, the proven technologies and other systems could be deployed to encompass the neighbouring ferry harbour, the village of Ballen and the district heating plant of Ballen-Brundby, and eventually the whole island [168], thus strongly increasing self-consumption, decarbonising heat and transportation and developing demand flexibility. A schematic representation of the Ballen Marina system is presented below, in figure 5.

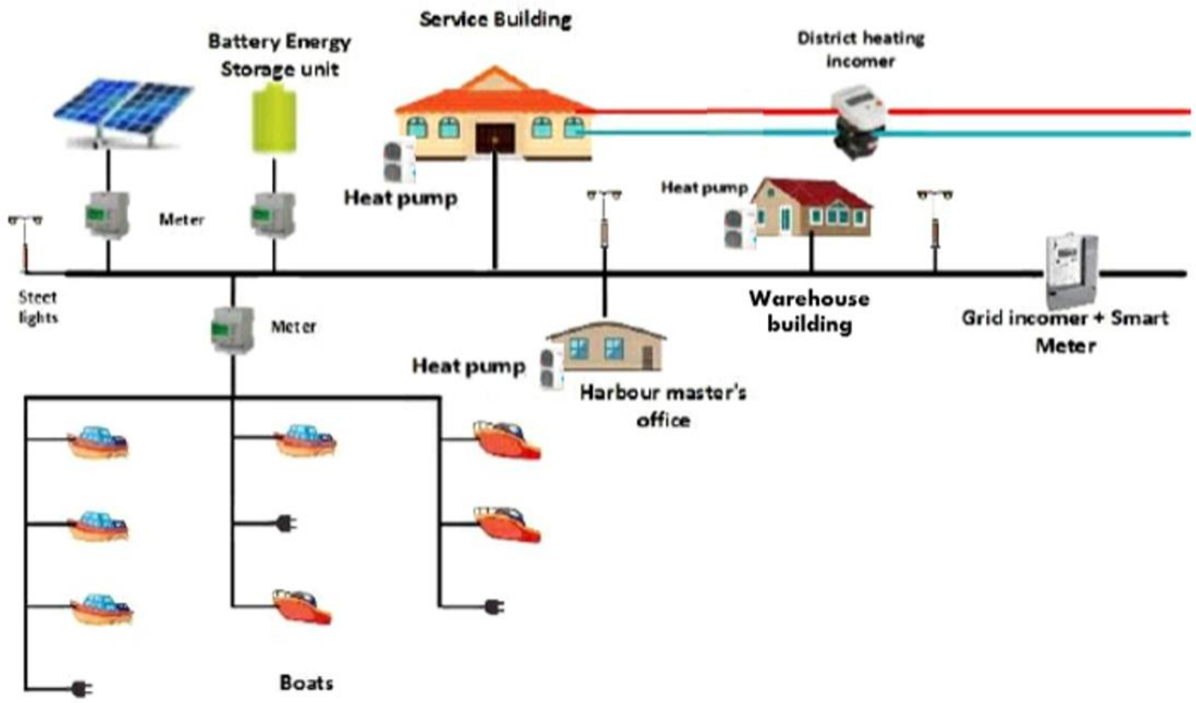

Figure 5 – Schematic representation of the electricity and heating system for the Ballen Marina with the SMILE improvements [169]

EU law concepts

Samsø may apply for the derogations attached to the status of an SIS or SCS, but it is unlikely that they get them as there are no major technical issues with the island's grid management [170]. Focusing on the Ballen Marina, there are opportunities to consider it as a CDS. However, deliverable D7.1's developments have shown that various factors have to be taken into account and that there is no legal certainty this may happen [171]. One of the issues was to decide whether the municipality, which owns the cables behind the meter to the public grid, is the final customer or whether the boats are, especially as most of the electricity consumption came from them. This was relevant in order to consider the marina's operator as a DSO or possibly as a CDS operator. The safest line of reasoning is to consider the marina as the final customer, which prohibits the qualification of CDS but opens the possibility to consider it as an active customer under EU law, allowing it to self-consume energy, store it, sell it to external actors, or provide flexibility services [172]. Finally, energy communities constitute a very attractive opportunity. Indeed, Samsø's population and institutions are used to participatory projects, with various community-owned wind turbines on the island. The marina could become part of a wider energy community (involving the ferry harbour, the village of Ballen and the Ballen-Brundby district heating plant – owned by the consumers in a non-profit company with limited liability – and eventually the entire island) which could potentially, depending on the relevant national legal regime, manage a part of the grid and if authorise to switch to island mode, create a microgrid, especially as the new Ballen Marina battery can regulate frequency and voltage levels to a certain extent [173]. Such a community could also apply for the derogations for the "less than 100 000 connected customers" regime to create a VIU, as detailed in section 3.1.2.

Potential use of the SMILE technologies for setting up microgrids

As part of the SMILE project, the Ballen Marina was able to produce electricity through a 60 kWp solar PV plant, which can be extended to reach 120 kWp in the future [174]. It could also store electricity via a 237 kWh battery with a 49 kW converter, allowing it to provide four hours of discharge at maximum capacity [175]. In addition, the demand of the heat pump of the warehouse' building and the sauna have been smartened to provide demand flexibility. In the future, other appliances may be smartened as well, such as "a sewage pump, […] a washing machine, a dryer, a circulator pump, ventilation in the service building and an electric vehicle charger"[176]. These new elements enable the marina to manage its peak demand, to self-consume as much of its electricity produced from solar energy as possible [177], and to potentially provide ancillary services to system operators. The battery even authorises the marina to set "a reference voltage and frequency" and to "be run islanded from the Samsø public grid"[178]. The Ballen Marina is therefore technically almost a microgrid in the sense that it has a PCC and enough generation and storage to maintain parts of its system (with some restrictions as the PV production and the battery cover only 47% of the marina's annual consumption under normal conditions [179]) if the public grid fails. Nevertheless, if the legal conditions in Denmark do not allow to disconnect, operate islanded and reconnect to the public grid, it will not be possible to really make use of this technical capability. This will be further discussed in section 4.2.1.3.

Participating in the flexibility markets

Given the increasing reservoir of flexibility available at the marina, it could provide ancillary services to the connecting DSO (KONSTANT in this case). The SMILE project on Samsø allows to consider offering voltage control support and voltage harmonics compensation [180]. The marina seems the perfect candidate to provide various ancillary services, especially if it qualifies as a balancing service provider [181]. However, some early field results show that the economic interest of flexibility activities will have to be thoroughly assessed, as currently, for example, there is little benefit for the marina to engage in energy arbitrage when the energy price difference between day and night is small. It might make more sense in the future, depending on market conditions and for example during winter, when there is less solar PV production to be stored. In addition, “the distribution network operator (KONSTANT) permits at most 50 kW injected into the public grid” in order to preserve the voltage level for the village of Ballen [182]. This limit restricts the volume of grid services that the marina may provide. Here, KONSTANT can be considered as the reserve-connecting DSO, as defined by the SO GL, thus getting a kind of veto right on the prequalification and activation of a reserve willing to offer services to the TSO [183]. A potential manner to overcome this 50 kW limit, to increase self-sufficiency and to provide more grid services is to include other potential flexible loads – such as the ferry harbour, the village of Ballen and the district heating plant, or even the entire island – into an energy community, potentially with grid management, the volume of flexibility to be offered to the grid operators may be much higher. However, the larger the installed capacity on the island, the more it relies on electricity exports to the mainland and the less interest there is in temporary islanding. Unless there is a strong interest in grid reliability in case of outages and an economically relevant possibility to provide black-start and grid-forming services, this outcome is unlikely to take shape.

3.4.3 Madeira

Overview of the island’s system

Madeira is the largest of the three SMILE islands in terms of geography, population and energy system. In 2016, it counted over 260 000 inhabitants and an installed generation capacity of 324 MW, the majority of which comes from fossil fuels, as shown in figure 6 below. Crucially, it is an energy island, not interconnected to the rest of the European internal energy market. This situation implies technical and economic challenges, as well as a specific legal regime. Indeed, this isolated situation deprives the Madeiran grid from the resilience of larger, interconnected networks. Consequently, it is challenging to increase the share of RESs, especially variable ones such as wind and solar PV, while maintaining stable voltage and frequency levels currently provided by the spinning reserves of thermal turbines [184]. It is this technical issue that has led the regional government to limit grid connections of full-injection micro-producers (rooftop solar owners) since 2014 and to only authorise installations entirely for self-consumption without any injection to the grid, thus slowing down the distributed PV’s uptake [185]. Despite this handicap, Madeira has aimed to get 50% of the electricity in its grid from RESs by 2020, compared to 30% in 2016 [186]. In the decade of 2020, it has aimed to shut down part of its thermal power plants, to significantly increase wind, PV and hydro power (including pumped hydro storage), to develop geothermal energy and to install a large battery (18 MW/15,6 MWh)[187]. The SMILE pilots aim to enable such transition by testing technologies authorising households and small businesses, EV owners and the grid operator to perform energy arbitrage and peak-shaving, and to provide frequency support and voltage regulation.

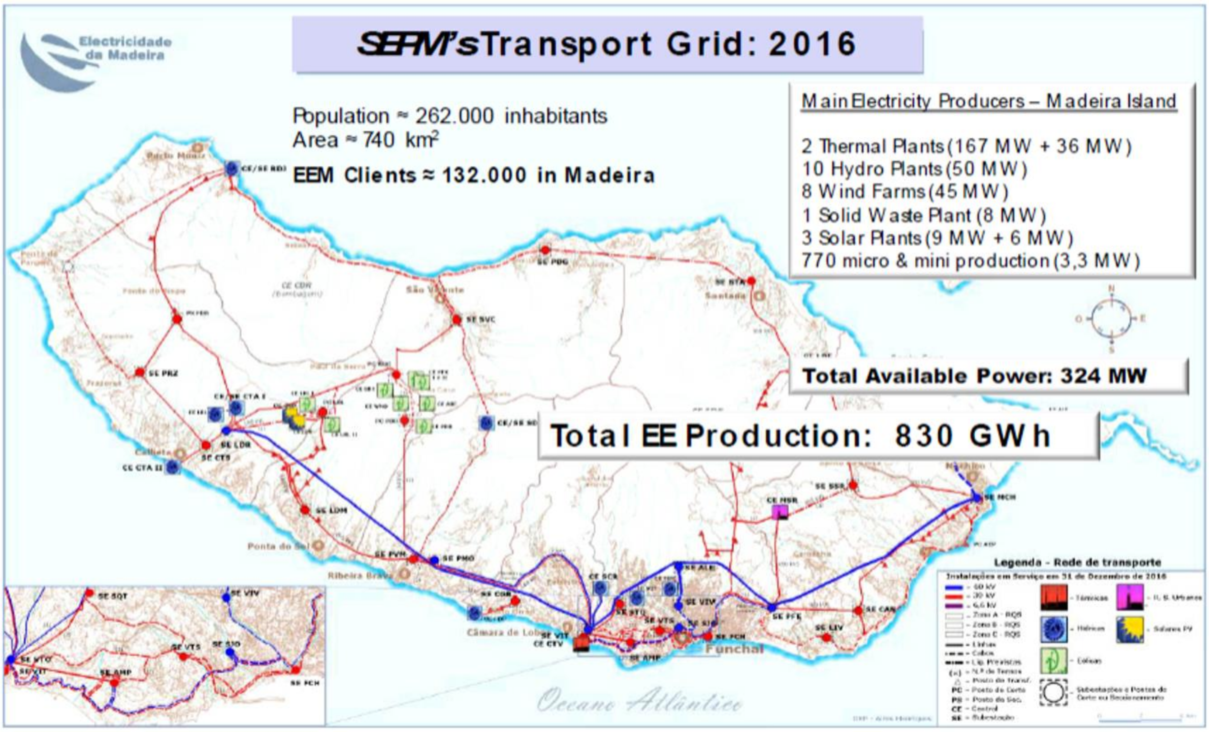

Figure 6 – Overview of Madeira's electricity system [188]

EU law concepts

As mentioned in the previous paragraph, and as explained in deliverable D7.1 [189], Madeira benefits from a specific legal regime. Indeed, following a 2006 Commission decision, the outermost region of Portugal is considered a micro isolated system and is indefinitely exempt from the main liberalised market rules: free choice of supplier, third-party access, market-based supply prices, unbundling rules, and so on. It is also exempt from the application of the network codes detailed in sections 3.2 and 3.3, although these can provide an interesting source of inspiration and benchmarks for Madeira's own set of network rules. However, there are two elements of the Directive's derogations that need to be addressed. First, article 3 of the 2006 decision states that the derogation "can be reviewed by the Commission if substantial changes occur in the electricity sector of Madeira"[190]. It may be possible for the Commission to consider the decreasing prices of the renewable energy generation systems (especially wind and solar PV) and flexibility technologies following the same trend (especially batteries), in particular when compared to the high average cost of electricity production on isolated systems, as a substantial change to the electricity sector. If this part of the decision is read in conjunction with article 66 (2) from the 2019 E-Directive, which states that derogations "shall be subject to conditions aimed to ensure that the derogation does not hamper the transition towards renewable energy", then a sort of indirect energy transition obligation seems to appear for Madeira's energy system operator. Indeed, if the operator makes insufficient progress while active customers, aggregators and medium-sized producers become technically and economically able to take the lead in such a transition, the European Commission may decide to revise any of the existing derogations, such as third-party access to the grid or free choice of supplier, in order to accelerate this change. Therefore, alongside the reasons of climate change and energy independence, EEM has another good reason to continue taking sustained steps towards a cleaner energy mix, as it is already doing. Secondly, the derogation does not encompass chapter III of the 2019 E-Directive, which contains the provisions for aggregation, active customers and energy communities. Although these did not exist in the 2003 Directive, when the Commission's decision was made, article 66 (1) of the 2019 Directive clearly does not intend to provide derogations to these provisions. Consequently, these have to be transposed into national law and such entities must be open to Madeirans, allowing them to access the relevant energy markets and to provide the network operator with the highly needed flexibility services.

Potential use of the SMILE technologies for setting up microgrids

The implementation of the SMILE project on Madeira is taking place by means of five pilots in five different locations. Pilots 1 and 2 involve dozens of households and small businesses to test behaviour changes. Out of this total, four households and one small business already equipped with PV panels received batteries (3 kW/8.6 kWh) and control systems in order to enhance self-consumption and allow energy arbitrage [191]. If these technologies are installed on the same section of the grid, they could be coordinated to offer ancillary services such as frequency support and voltage regulation [192]. These services could be offered by active customers, through an aggregator, or by setting up an energy community. If authorised by national law and the local network code, such actors could also develop islanding capacity and, if the grid operator is interested, offer their flexible resources, including for load-shedding when the rest of the grid is too congested. Pilots 3 and 4 refer to EV smart charging systems. The first pilot applies to a pair of light EVs, while the second gathers numerous full-fledged EVs parked in the grid operator's garage, offering 420 kWh of flexible capacity [193]. Once these technologies are proven, EVs can be integrated into the flexibility activities of active customers and energy communities. Finally, pilot 5 consists of the installation of a battery (40 kW/80 kWh) at a medium voltage/low voltage distribution station (*Fazendinha*) that collects the electricity from PV micro-producers with full grid injection that is not consumed at low voltage level, for a total local installed capacity of 38 kWp [194]. This battery is operated by the SMILE partner company PRSMA. It provides voltage support as well as peak-shaving to limit fluctuations in solar PV production, which negatively affect the network [195]. At the moment, none of these technologies is designed to island a part of the network and create a microgrid.

Participating in the flexibility markets

On Madeira, the grid operator has a choice: it can either invest in flexibility technologies such as batteries on its own, it can consider it more appropriate (economically, socially or time-wise) to let active customers, aggregators and energy communities develop and provide such services, or it can adopt a mix of both, depending on the Madeirans' willingness and capacity to invest in such equipment and on the grid's needs in each section. If EEM is to own and operate flexibility assets, there should not be many legal barriers as it can already act as producer, DSO, TSO and supplier. However, if such assets (e.g., stationary batteries or EVs) are to be owned and operated by active customers or energy communities, the grid operator, EEM, will have to create signals to request their ancillary services against a possible remuneration. Given that Madeira's grid is extended and that grid problems are more likely to appear in some sections rather than others, a locational price may be of interest and would thus have to be integrated in the relevant legislation or code. Also, it may be of interest for the local lawmaker to set up clear procedures to authorise the ownership and operation of parts of the grid by energy communities and to authorise their islanding under some conditions.

3.5 Summary

Microgrids are not defined nor regulated under EU law. However, this chapter used the results of the literature review presented in chapter 2 to identify three criteria that would be needed to legally define microgrids: it needs to fulfil the requirement that the network is local and/or of a small size, it must use flexibility resources and it must be capable of temporary islanding. Then, these three criteria were used to assess the degree of microgrid friendliness of various network operation regimes in EU law, i.e. the general distribution grid operation rules, the "less than 100 000 connected customers" exemption, isolated systems, CDSs and energy communities. The first outcome is clear: there is no existing regime under EU law that would qualify as microgrid. The second outcome is that energy communities meet most of the requirements for becoming a microgrid, if the national legal regime allows the energy community to own and operate a grid and except for the possibility of temporary islanding.

We have noted that the process of islanding consists of three phases: a disconnection from the public grid followed by a temporary islanded operation and, finally, a reconnection (with resynchronisation) to the public grid. In addition, microgrids need to have an internal black-start capacity so that they can ensure that their network can run in islanded mode for as long as necessary. As temporary islanding is not regulated by the 2019 E-Directive and E-Regulation, we studied the network codes: a set of technical regulations directly applicable in EU MSs and although especially directed towards TSOs, they sometimes also are relevant for DSOs. The analysis of the three relevant network codes showed that they do refer incidentally to the three stages of islanding as well as black-start capability but are not sufficiently equipped to facilitate the operation of microgrids. Hence, if the EU legislator opts to introduce microgrids, network codes have to be checked and amended in order to guarantee that these grids can get temporarily islanded and to clarify how existing qualifications could apply to them (PGMs, PGFs, defence service providers or restoration service providers – alternatively or in a combined manner).

Aside from the need to define the concept of microgrids, there is a need to consider the way in which the development of microgrids can be incentivised by making use of their flexibility potential to provide services to external parties. Indeed, microgrids can aggregate their internal flexible resources and offer part of it to third parties operating outside the microgrid (grid operators or BRPs). In addition to help integrating more variable RESs into the public grid, selling flexibility services may allow microgrids to recoup their investments faster and to improve their business case. Consequently, the possibility that microgrids sell flexibility services to third parties may be crucial for their development. Our analysis of the 2019 E-Directive, E-Regulation and network codes show microgrids, potentially, could offer ancillary services. Microgrids could be considered as a market party and thus have access to all relevant markets, including markets for ancillary services. Moreover, microgrids could certainly be considered as BRPs or become BSPs and offer such services to their connecting DSO or even to their TSO. In addition, they could potentially offer voluntary islanding (also called load-shedding) as a demand response service and black-start services to the interested grid operators (DSO or TSO). They could also provide more classic flexibility services such as frequency support, voltage regulation or local congestion management. However, in case microgrids will be introduced in EU law, the network codes need to be thoroughly checked and amended to facilitate the development of this particular type of grid. If microgrids are properly incentivised and can benefit from legal certainty, they can constitute a valuable asset to help maintain network stability at the best cost.

Finally, this chapter studied the application of EU law for microgrid development on the SMILE islands: Orkney in the UK, Samsø in Denmark and Madeira in Portugal. Although EU law concepts may apply very differently to these islands, all three islands present a real potential to develop energy communities (or their like in the UK). The possible development of microgrids on these islands is more complex due to two factors: the local electricity systems and the SMILE technologies implemented are basically not designed for temporary islanding (apart to an extent on Samsø).

4 Microgrid provisions in national legal frameworks

Although microgrids are not defined and regulated in EU law, they are neither in the national laws of the SMILE countries: the UK, Denmark and Portugal. This chapter will nevertheless assess these national laws and the national network codes in order to establish whether (parts of) the regime may meet the three criteria of being a microgrid as presented in section 3.1. Then, it will investigate the extent to which microgrids can be incentivised by allowing them to operate on the flexibility markets. Finally, it presents the results of a questionnaire sent to other EU MSs with islands about the existence of a legal regime for microgrids.

4.1 The UK

The SMILE deliverable D7.1 already presented the policy and law making institutions in the UK, with a focus on energy and energy storage in particular [196]. Since writing D7.1 in 2019, two important changes have taken place: Brexit and, for the energy sector, the publication of the December 2020 Energy White Paper (see further below).

On 31 January 2020, the UK left the EU. Immediately a transition period followed, which ended on 31 December 2020. During this time, the UK Government and the EU negotiated the framework of their new relationship and concluded the Trade and Cooperation Agreement [197]. This agreement includes a title on energy, including a chapter on electricity and gas [198]. Its content aims to provide a basic level of harmonisation of the rules governing the UK and EU electricity and gas markets. For instance, article 5 (1) requires the parties to ensure a non-discriminatory regulatory framework for the production, generation, transmission, distribution and supply of electricity and natural gas. Article 5 (2) then requires each party to guarantee customers' free choice of supplier. Subsequently, article 6 (2) states that each party must ensure that balancing markets are non-discriminatory, that services are defined and procured transparently, and so on. Yet, it is also specified that each party maintains the right to regulate its sector in order to achieve "a legitimate public policy goal […] based on objective criteria", especially with regards to small or isolated markets [199]. Consequently, one can expect that on the short term and given the long history of the UK as an EU MS, the fact that most of the large energy operators in the UK are European owned and have well established multinational business operations across continental Europe, the UK and EU rules regarding the electricity sector will continue to follow similar paths.

The Energy White Paper is a policy document that aims to detail and foster the completion of a "Ten Point Plan" presented by the Prime Minister [200] towards the final goal of reaching net-zero emissions by 2050. While microgrids are not mentioned in this important document, one can expect that its "Greener Building" and "Zero Emission Vehicles" items will be relevant for improving flexibility services and thus may facilitate the development of microgrids [201].

4.1.1 Possibilities for microgrids under UK law

This section is organised following the same logic as the previous chapter on EU law. First, we search for a definition of microgrids. Next, we assess whether the existing regime can be used to further develop microgrids. After that, we present elements on how potential microgrids can sell ancillary services to network operators. Finally, we apply these results to the case of Orkney.

4.1.1.1 Definition

Although there is no legal definition of microgrids in UK law, Ofgem, the British NRA, categorised local energy archetypes in 2017, and notably this included microgrids [202]. Microgrids are described as "decentralised grids which operate in parallel to or independent of the national grid"[203]. It is unclear whether the notion of operating "in parallel" can be considered as an equivalent for temporary islanding. It also provided several examples of such microgrids in the UK: the Centre for Alternative Technology Micro-grid, the Isles of Scilly, the Isle of Eigg and Knoydart. The problem is that only one of these four systems seems to tick all the boxes of the definition of a microgrid as established in this report (see section 2.3). The other three systems are actually small, permanently connected or permanently isolated grids. This is also the conclusion reached in a report from XE, which reads: "As far as XE is aware, there is at time of writing only one such operational true microgrid in the UK (at the Centre for Alternative Technology (CAT), in Wales)"[204]. This confusion on the concept of microgrid is basically a direct result of a lack of definition in UK legislation. Nevertheless, in the following section, we will try to identify whether the law contains some elements that could help develop microgrids.

4.1.1.2 Existing legal qualifications useful to microgrids

In terms of the electricity legislation in the UK, the 1989 Electricity Act is the most important text. In it, the relevant definitions and regimes are set for electricity market actors. As there is nothing on microgrids in this act as such, we looked for the existing legal qualifications that could fulfil the three criteria used in section 3.1: small and local, flexibility use and temporary islanding.

General distribution grid operation rules and the unbundling exemption

Article 4 (1) of the 1989 Electricity Act prohibits any person to undertake generation, transmission, distribution or supply activities without a licence. These licences are granted by the competent authority [205], and it is specified that a distribution licence holder cannot also hold a generation or supply licence [206]. This is the DSOs' unbundling rule. The distribution licence regime does not provide for an unbundling exemption with regards to "less than 100 000 connected customers" as is proposed under EU law and detailed in section 3.1.2. However, article 5 of the Act provides that exemptions from the obligation to hold a licence can be granted. The conditions for such exemptions are presented in the Electricity (Class Exemptions from the Requirement for a Licence) Order 2001. Schedules 2, 3 and 4 present the exemptions for generation, distribution and supply, respectively. These can be combined in order to create small size VIUs. Schedule 2 of the Order indicates the generation exemptions. Class A generation exemptions define small generators as:

> Persons […] who do not at any time provide more electrical power from any one generating station than—
> (1) 10 megawatts; or
> (2) 50 megawatts in the case of a generating station with a declared net capacity of less than 100 megawatts;
> disregarding […] power supplied to […] a single consumer who occupies premises which are on the same site as the premises where the generating station is situated and who consumes all the power provided to him from that generating station at those premises or supplies all or some of such.

In schedule 3, Class A focuses on small distributors. Such actors "do not at any time distribute more electrical power than 2.5 megawatts for the purpose of giving a supply to domestic consumers". Finally, schedule 4's Class A exemption about small suppliers targets those "who do not supply any electricity except electricity which they generate themselves and who do not at any time supply more electrical power than 5 megawatts of which not more than 2.5 megawatts is supplied to domestic consumers." The class exemption regimes are very important for all non-traditional electricity developments, and we will refer to them again, but these exemptions already make it possible to understand that in the UK it is not the number of connected customers that constitutes a threshold for derogations to unbundling but rather the volumes of energy generated, distributed and supplied. Consequently, a (community) grid (as detailed in section 2.1.3) with an installed capacity of up to 10 MW, distributing and supplying a maximum of 2.5 MW to domestic consumers and possibly an additional 2.5 MW to non-domestic consumers (such as businesses or shared services sites) does not have to be unbundled and could be managed by a VIU. This regime seems to broadly comply with the small size and localness criterion that is relevant to qualify a microgrid and it can be deduced that it will need flexibility in order to remain balanced. However, the remaining question is once again temporary islanding.

Isolated systems, CDS and private wire networks

In 2011, a note from the Department of Energy and Climate Change detailed the transposition measures taken in UK law to comply with the 2009 Electricity Directive [207]. This document explains that the derogatory regime for isolated systems "does not apply to GB"[208]. The 2011 note, however, specified that the 1989 Electricity Act was amended to include CDSs and to exempt them from the approval of tariff methodologies by Ofgem [209]. Schedule 2ZA of the 1989 Electricity Act, regulation 12 (1) provides that a distribution exemption holder (under schedule 3 of the class exemption regime detailed above) can apply for its system to be classified as a CDS. According to regulation 12 (2) the competent authority may authorise such a classification. The criteria are very similar to the ones set in EU law and essentially apply to a self-contained site with no or few domestic customers and that mainly generates its own electricity. Similarly to EU law (see section 3.1.4), this is a legal regime designed for industrial and commercial sites, not for households.

In addition to the above, UK law contains the concept of a private wire network. This system is defined in article 32 B of the 1989 Electricity Act. It states that electricity is supplied through a private wire network if it is conveyed to premises by a system used for conveying electricity from a supply-licence-exempt generator to one or more customers directly by this operator or by another small supplier [210]. Therefore, this system refers to the Class Exemptions Order seen earlier. Although it is referred to in various documents about legal options for the development of local energy systems [211] and it may fulfil the requirement of localness and possibly the flexibility criteria, it does not facilitate temporary islanding and thus cannot be considered as a microgrid.

Community energy projects

The UK has neither transposed the 2018 RES-Directive nor the 2019 E-Directive and therefore has not integrated into its legislation the concepts of RECs and CECs (see section 3.1.5). However, UK law contains a concept comparable to energy communities: community energy projects. In the UK, "community projects have made fast progress in renewables investments over the past 20 years. In 2017, the UK community energy sector owned a total electrical generation capacity of 249 MW"[212]. This may be partly due to the 2006 Climate Change and Sustainable Energy Act recognising "community energy projects". Article 19 (1) and (2) of the Act require the Secretary of State to promote them and to provide advice and assistance to persons establishing and operating, or proposing to establish and operate community energy projects. Community energy projects are defined by the installation and/or use of "a relevant plant for a community purpose"[213]. A relevant plant is an electricity generator with maximum capacity of 20 MW or a heat producer with maximum capacity of 100 MW thermal, using RESs [214]. A community purpose means generating electricity or heat wholly or mainly within qualifying premises, which in turn refer to premises used wholly or mainly for purposes other than carrying out a trade, business or profession and, if they mainly contain dwellings, they contain at least five of them [215]. The spirit of these community energy projects is quite similar to that of the CECs and RECs but they are not entitled to undertake as many activities nor can they operate their own grid. Hence, the grid serving these community energy projects is either operated by an unbundled DSO or by a VIU, if the conditions from the Class Exemption Order are fulfilled. Such a system can be local, of a small size and use flexibility resources. However, none of these existing legal qualifications in UK law explicitly permits temporary islanding.

4.1.1.3 Islanding in network codes

Given the absence of provisions governing temporary islanding in UK energy law, one must turn to network codes in order to identify the provisions relating to its three phases: disconnection, islanded operation and reconnection. Black-start, which is needed internally to secure the grid, is also part of this research. The main network code in the UK is simply named the Grid Code. It applies mostly to the transmission grid, but it contains a long list of definitions that apply to distribution systems [216].The concepts defined in the Grid Code, their activities or their size limits may therefore be relevant for the development of microgrids. Apart from the Grid Code, we also will analyse a network code and two standards that are specific to the distribution grid: the Distribution Code (Dcode) and Engineering Recommendations G98 and G99.

The Grid Code defines the essential actors of the electricity system in a broader sense than the 1989 Electricity Act, especially because it considers, for technical purposes, generators, distributors (called "network operators") and suppliers as such, even when they are exempt from having a license [217]. Similarly to the RfG NC (see section 3.2.1), it defines power stations (equivalent to RfG NC's PGFs), PGMs and power park modules [218]. It also sets the thresholds between the different types of PGMs. These are very similar to the RfG NC thresholds provided in table 7 (see section 3.2.1), at the exception of type C PGMs starting at 10 MW and type D PGMs at 50 MW [219]. In addition, the Grid Code defines a small power station as a power station directly connected to the transmission system or embedded within a user system (e.g., at distribution level) and with a registered capacity that depends on its location. For Northern Scotland, where Orkney lies, the cap is set at 10 MW [220]. The classification as a small power station implies specific requirements for the connection and operation of both the PGMs and the small power stations itself For example, the Grid Code chapter on European connection conditions provides mandatory voltage control requirements for types C and D, similar optional requirements for type B and nothing about type A [221]. The section on fault-ride-through (FRT) only applies to types B, C and D [222]. Type C and D must provide ancillary services [223], and so on. Similarly, the chapter on Connection conditions (CC) of the Grid Code, which establishes the technical criteria that users need to comply with, does not apply to small power stations [224]. Taken together, these elements seem to demonstrate that a potential microgrid considered as a small power station and relying on type A PGMs would have very limited technical obligations, while another microgrid with type B PGMs would have to comply with a number of such technical requirements, although often in a non-mandatory manner. It then depends on the planned installation and the project developers to check the applicable rules.

The Grid Code is also relevant when it comes to the phases of temporary islanding. The Grid Code provides definitions regarding de-synchronise and re-synchronisation [225], de-synchronised island [226] and power island [227]. These can relate to the three phases mentioned earlier in this section. The first three are rather self-explanatory, while power islands are defined as Generator sets (Gernsets) "at an isolated Power Station, together with complementary local Demand. In Scotland a Power Island may include more than one Power Station." A power station is: "[a]n installation comprising one or more Generating Units or Power Park Modules or [PGMs] or Electricity Storage Modules (even where sited separately) owned and/or controlled by the same Generator, which may reasonably be considered as being managed as one Power Station"[228]. Therefore, temporary islanding and its different phases exist in the Grid Code. However, the question of how to activate it and who can do so is not solved.

According to the Grid Code, generators must either remain connected [229] or be automatically disconnected without the possibility to automatically reconnect to the grid [230], except for participants connected to an industrial network who may, under certain conditions, be permitted to operate isolated from the rest of the system if agreed beforehand [231]. Aside from this option for potential industrial microgrids, the other limited option for islanding is through the provision of black-start services to the TSO (see further below section 4.1.1.4). Nevertheless, it can be noted that the provision of black-start services is apparently only considered for type C and D PGMs [232], meaning that the technical requirements will only apply to these PGMs. The rules for internal black-start activation will in the end remain the responsibility of the microgrid operator once islanded, but type B PGMs or a group of interconnected and interoperated type A PGMs should explicitly be authorised to undertake black-start, if they are willing.

The Dcode generally recognises the same actors and provides similar rules in its logic as the Grid Code. However, it contains several roles and regimes that may be of particular interest to potential microgrids. It, for example, defines a Customer With Own Generation (CWOG) as: "[a] Customer with one or more [PGMs] connected to the Customer's System, providing all or part of the Customer's electricity requirements, and which may use the DNO's Distribution System for the transport of any surplus of electricity being exported"[233]. In essence, it corresponds to the active customer mentioned in the 2019 E-Directive (see section 3.1.5.1), albeit not as detailed. This may be relevant for setting up prosumer consortium types of microgrids.

Since April 2019, new PGMs to be connected to the distribution network have to comply with Engineering Recommendation G98 or G99 [234]. Engineering Recommendation G98 applies to microgeneration with a maximum installed capacity of 7.36 kW (including battery storage)[235]. In this case there is only a need to inform the DSO. This size of installation may be suitable to a household but not so much to microgrids. In that case, Engineering Recommendation G99 may apply instead. This standard applies to type A to D PGMs to be connected at distribution level [236]. Chapter 9 of this standard contains a section about island mode. It states that it is up to "the DNO to decide, dependent on local network conditions, if it is desirable for the Generators to continue to generate onto the islanded DNO's Distribution Network" when a fault or planned outage takes place [237]. If an agreement is reached between the potential microgrid and the connecting DNO, then in case of outage the microgrid could switch to island mode and "maintain continuity of supply to the portion of the Distribution Network containing the [PGM]"[238]. This is encouraging, although there is uncertainty about the DNO's requirements and decision power, and this applies only to outage situations. It would be more incentivising for potential microgrids if DNOs have published the generally expected requirements beforehand and if the possibility to voluntarily switch to islanded mode outside emergency situations was allowed too.

In sum, the only provision applying to a disconnection of the distribution network is included in Engineering Recommendation G99, which allows the local DNO and the generator to agree on islanding operation in case of an outage. In order to develop microgrids it would need a provision enabling temporary islanding outside emergency situations (of course according to rules set by DNOs) and explicitly enabling owners of type A and B PGMs to undertake black-start, which is currently reserved for type C and D PGMs. Regarding black-start and flexibility services, the rules for selling ancillary services are discussed in the following section.

4.1.1.4 Microgrids' participation to flexibility markets

As explained in section 3.3, the development of microgrids needs to be incentivised, for example, by allowing them to sell flexibility services to third parties, including to their interconnected DSO and to the TSO.

We start with the provision of black-start services. In the Grid Code, black-start capacity is defined as "the ability for at least one of a Black Start Station's Gensets to Start-Up from Shutdown and to energise a part of the System and be Synchronised to the System upon instruction from the TSO, within two hours, without an external electrical power supply"[239]. The only technical requirement mentioned here is that such a service is provided within two hours. The notion of black-start capacity is then mentioned various times in the Grid Code, linked to the power islands, themselves linked to the System Restoration Plan [240], referring to the E&R NC (see section 3.2.1). The exact procedure to re-establish a working network after a blackout requires to re-energise from scratch various power islands (see section 4.1.1.3) which are then interconnected and expanded to the whole grid [241]. One can imagine that a multi-microgrid system could be well suited to create interrelated power islands and increase Great Britain's resilience to a black out. This is actually the core idea of a project taking place in the UK and involving the TSO: Distributed ReStart [242]. However, as explained in section 4.1.1.3, the provision of black-start services to the TSO is only considered for type C and D PGMs [243], thus excluding most of the potential microgrids.

When the public grid is not on emergency state, microgrids can offer various flexibility services to the public grid, just as other market participants. In this regard, it is important to refer to two recent and very critical reports on the development of and access to flexibility markets in the UK. In a 2019 report, Great Britain's flexibility market is poorly ranked amongst European countries [244]. Although markets are generally open to all forms of flexibility, aggregation is enabled for most of the balancing services and DNOs have been tendering and procuring flexibility services to solve congestion [245]. A report from December 2020 claims that DSOs "procure flexibility services on a pilot basis, but without a comprehensive framework foreseeing transparent, non-discriminatory and market-based procurement. Local flexibility markets are still in their infancy"[246]. Additionally, the UK has not "adopted a framework to adequately remunerate DSOs for the procurement of flexibility services" nor has it defined standardised market products for flexibility services [247]. Moreover, "the balancing mechanism cannot be really considered to be a market, as bids and offers are accepted by the TSO at its sole discretion" and limits are set "to the participation of independent aggregators"[248].

When considering in more detail and analysing the Grid Code with regard to the provision of balancing services, it appears that size issues raised earlier about offering black-start services exist here as well. The Grid Code contains a Balancing Code that deals with balancing market unit data and participants. This Balancing Code only applies to large power stations [249]. It specifies that large power stations with a registered capacity of less than 50 MW comprising of Power Park Modules are not authorised to submit bids [250]. These minimum installed capacity requirements to provide balancing services are most likely too high for potential microgrids, except perhaps for industrial ones.

All in all, it is difficult to perceive how microgrids, especially non-industrial ones, can provide black-start and other ancillary services to grid operators. Currently, most of the services are to be provided by relatively large generators (i.e., type C and D PGMs), the procurement of ancillary services by DNOs is not mainstreamed, rules are complex and fragmented and even independent aggregation participation is limited. If the UK network is to leverage the flexibility capacities of microgrids, a regulatory reform is needed, enabling type B PGMs and small power stations to provide such services, simplifying and streamlining access rules and product types, bringing transparency to the markets and treating aggregators on an equal footing with other flexibility providers.

4.1.2 Application to Orkney

Deliverable D7.1 showed that energy regulation is mainly decided at national level in the UK [251]. Scotland's competence in this field is very limited and Orkney enjoys no particular regime. However, there is potential, mainly driven by grid constraints and "a thirst for local supply arrangements"[252].

Based on this analysis, applying the existing legal regime in the UK to Orkney to further develop the SMILE project activities may translate as follows. It may be possible to group local distributed flexibility sources, for example, inside the same ANM zone, as explained in section 3.4.1, inside a licence-exempt company potentially engaged in generation, distribution and supply. This would allow for a VIU controlling up to 10 MW of generation and distributing and supplying a maximum of 2.5 MW at a time to domestic consumers and possibly an additional 2.5 MW to non-domestic consumers (such as businesses or shared services sites). Otherwise, it will depend on the local unbundled DSO (SSEN) to operate such a grid. In order to operate as a microgrid, the main obstacle is still islanding and the provision of flexibility services – other than maximising self-consumption and limiting curtailments, as is already done – given the small size of these installations. Indeed, in the existing network codes, islanding through the formation of power islands providing black-start services and the provision of ancillary services is limited to type C and D PGMs, and are thus reserved for generation capacities higher than 10 MW. Yet, at distribution level, the DNO (SSEN) can agree with local actors on the conditions for islanding in order to maintain supply, but only in case of an outage.

Finally, rules regulating Orkney's market are evolving. Ofgem has, for example, conditionally authorised the construction of a new 220 MW transmission cable from Orkney to mainland Scotland, which is significantly more than the current connection capacity of 40 MW. The condition involves the need to demonstrate by the end of 2021 that at least 135 MW of new generation capacity will be connected to the grid in Orkney relatively soon [253]. However, this is unlikely to fully solve the existing curtailment issues given that congestion mostly arises within Orkney's grid. Such a development will not hamper the local market for flexibility but it will reinforce the importance of electricity exports to mainland for generation installed in Orkney and may logically reduce the interest in creating microgrids.

4.2 Denmark

SMILE deliverable D7.1 provides many contextual elements about energy policy and law-making in Denmark [254]. However, the word microgrid (or *mikro-elnet* in Danish) does not appear in the country's main energy policy document: The Energy Strategy 2050 [255]. At best, one can find an indirect opportunity for developing microgrids through the increasing need for demand response and flexible generation, as indicated by the TSO, Energinet, in its Strategy Plan 2010 [256]. Energinet has also run a demonstration project named *Celleprojektet* (the cell project) about grid islanding from 2005 to 2011 [257]. Although the pilot to prevent a black-out was a success, the TSO has not undertaken more research in this field. The main reason may be that Danish electricity supply is already extremely stable and there is not much need for islanding and black-start capacities. Nevertheless, this is a point that is discussed in detail below.

4.2.1 Possibilities for microgrids under Danish law

Denmark is an EU MS, meaning that the legal regime detailed in chapter 3 is fully applicable there. This research starts with the cornerstone of the regime of the Danish electricity system: the Electricity Supply Act (*Elforsyningsloven*), in its latest version dated 6 February 2020. In addition, a number of amending acts have been adopted more recently to transpose the 2019 E-Directive.

Searching for a legal regime adapted to the development of microgrids in Denmark, this section is organised in four parts: (i) definition, (ii) existing legal qualifications useful to microgrids (iii) islanding in network codes and (iv) the possibility that microgrids may offer flexibility services to third parties.

4.2.1.1 Definition

The term microgrid is not defined nor mentioned in the Electricity Supply Act or in any other law, regulation or network code we have consulted. It does not seem to be a concept used in the Danish context. However, some elements from the existing legal regime may be of use for the development of microgrids in Denmark, as will be explained below.

4.2.1.2 Existing legal qualifications useful to microgrids

The Danish Electricity Supply Act regulates the production, transport, trade and supply of electricity. Its last integrated version, dating from 6 February 2020, does not mention microgrids. Therefore, we looked for the existing legal qualifications that could fulfil the three criteria used in section 3.1: small and local, flexibility use and islanding.

General distribution grid operation rules and the exemption regimes

The Danish Electricity Supply Act defines what a distribution network (*Distributionsnet*) is and specifies that it is a network intended to supply electricity to an indefinite number of customers [258]. The distribution network is operated by a licensed DSO (*Netvirksomhed*)[259] which is legally unbundled from generation and supply companies [260]. Therefore, although not prohibited, a Danish DSO does not have a size or localness component. Flexibility may of course be used but temporary islanding is not part of the current regime.

According to the Electricity Supply Act, the Minister of Climate, Energy and Utilities may decide to exempt DSOs from the unbundling rules if the DSO (alone or together with other DSOs within the same VIU) has less than 100 000 connected electricity consumers [261]. In other words, this is only an option, subject to the Ministry's decision. It should be noted that in any case, accounting unbundling still applies, even if such exemption is granted [262]. As a consequence, although it is interpreted a bit more strictly than in EU law, the "less than 100 000 connected customers" exemption exists in Danish law and may be used to create VIUs. Yet, the islanding issue remains.

With regard to isolated systems, these are mentioned in a somewhat old version of the Electricity Supply Act only to require the competent ministry to adopt rules on the matter [263]. As explained in section 3.1.3, there is not much for potential microgrids in this legal qualification anyway. Apart from these two possibilities, we surprisingly have not found a definition nor a regime for CDSs.

Energy communities

The Act amending the Electricity Supply Act, adopted on 29 December 2020, transposed the 2019 E-Directive and introduced new definitions. The most relevant here integrate into Danish law the concepts of aggregation (*Aggregering*), active customer (*Aktiv kunde*), citizen energy community (*Borgerenergifællesskab*), energy storage (*Energilagring*) and non-frequency ancillary services (*Ikke frekvensrelateret systembærende ydelse*)[264]. These definitions are completely or largely consistent with those in the directive and are detailed in section 3.1.5 of this deliverable.

The December 2020 Executive Order on Citizen Energy Communities addresses the tasks and obligations of CECs, electricity trading companies and public electricity supply companies (DSOs and TSOs) in relation to the sharing, consumption or production of electricity within a CEC [265]. It therefore affects CECs and all actors CECs will have to deal with, especially to exchange energy between their participants. The order's general provisions (art. 3 to 5) as well as those relating to the activities CECs can undertake (art. 6 to 9) are fairly similar to those of the 2019 E-Directive. There are, however, two distinctive elements. First, article 5 explicitly prohibits CECs from owning, establishing, purchasing or renting distribution networks. This will therefore pose an issue for the use of the legal qualification of CECs for developing microgrids in Denmark. Indeed, a microgrid CEC would then be obliged to rely on a DSO to organise the sharing of electricity within the community. This should be possible, as article 13 specifies that network companies must cooperate with CECs to facilitate such sharing, in return for compensation determined by the NRA (*Forsyningstilsynet*). In the case of a potential microgrid regime, the local DSO should be willing to organise electricity sharing behind the PCC, and must also accept that grid-islanding hardware and software are to be implemented in part of its grid. These additional conditions render the possibility of setting up microgrids more elusive. Secondly, article 8 (2) requires that a CEC be established as an electricity trading company or as an aggregator company and that it be subject to all relevant rules in order to participate directly in the electricity market. This has the merit of providing clarity on the possible qualification of a CEC. The CEC regime may be a proper basis for developing microgrids. However, the prohibition to operate its own grid and the absence of any mention of temporary islanding are two major barriers.

4.2.1.3 Islanding in network codes

Adopting the same approach as in the 2019 E-Directive (see section 3.3.1), the December 2020 Act amending the Electricity Supply Act introduced the notion of islanding capacity (*Ødriftkapacitet*) into Danish law [266]. Together with black-start capacity (*Dødstartskapacitet*), it is part of the list of non-frequency ancillary services that network operators can use. *Ødrift* does not appear anywhere else in the Electricity Supply Act, the Act amending it or the CEC Order. Where it does appear, however, is in network codes and particularly in the grid connection codes for generation, implementing the EU RfG NC (see section 3.2) in Denmark. As network codes directly apply in the EU MSs, provisions discussed below are only issued by the relevant actors (TSOs and DSOs) to reach a higher level of detail when needed or as transitory measures. For islanding, including its three stages and internal black-start, the conclusions of section 3.2.3 therefore apply to Denmark too.

For the connection of new generation and demand facilities, Energinet applies the RfG NC and DC NC but provides lower PGM thresholds in comparison to the ones indicated in table 7 of this deliverable (see section 3.2.1)[267]. These thresholds are presented in table 8 below.

Table 8: Thresholds for PGM types in Denmark.

PGM type	A	B	C	D
Threshold	0,8 kW	125 kW	3 MW	25 MW

As a result, if a potential microgrid would be considered as a PGM or as a PGF gathering PGMs according to the RfG NC, it will most likely apply the rules for type B and potentially type C. Although a type D generator should not be ruled out for an industrial microgrid, as that is actually the only type of PGM that is required to be able to island according to annex 1 of the 2018 Danish regulation [268].

In addition to the above, plants connected to the distribution network are also subject to technical conditions issued by the network companies. The requirements separate between connections to low-voltage networks by type A and B generators on the one hand [269] and connections to medium- and high-voltage grids by type B, C and D generators on the other [270]. Both documents define the meaning of *Ødrift* and specify that it is an undesirable situation typically created by frequency changes and that the network protection rules require that in such case the production plant should be disconnected [271].Last but not least, the idea that islanding is an undesired situation can also be found in the requirements for the connection of storage facilities [272], while it is not even mentioned in the rules for the connection of new demand facilities above 100 kW [273].

4.2.1.4 Microgrids' participation to flexibility markets

In this part, we examine the rules in Denmark regarding (i) black-start services to be offered to the TSO and (ii) reserve supply to Danish islands given that these are within the realm of the specific capabilities of microgrids. Afterwards, we address the opportunities and barriers for microgrids to provide flexibility services to third parties in order to enhance their economic situation.

Given the high level of reliability of the Danish electricity system, Energinet (the TSO) only sees a limited need for contracting facilities with black-start capabilities. It has established that having two technically independent providers of black-start services located in each part of the country (DK1 and DK2) is sufficient [274]. Since Denmark consists of a peninsula and various islands, it is separated in two electricity market areas. DK1 covers Western Denmark (Jutland-Funen, etc.), while DK2 covers Eastern Denmark (Zealand, Lolland, Falster, Bornholm, and others)[275]. The requirements for offering such services are as follows: be connected to the 150 kV grid in DK1 or the 132 kV in DK2, have a minimum installed active power capacity of 30 MW and be able to handle instantaneous jumps of ± 10 MW, be able to handle the reactive power required depending on the geographical location of the plant in the network, be able to continuously operate for at least 24 hours and provide two maximum load starts within 12 hours [276]. These requirements set the bar very high compared to the capacity of most of the potential microgrids, except for some industrial ones. Nevertheless, we would not recommend lowering the thresholds, given the absolute importance of the reliability of such services, except if Energinet would see an interest in a multi-microgrids system, similar to the project undertaken in the UK (see section 4.1.1.4).

Regarding the reserve supply for Danish islands, Energinet identifies several needs that must be met in order to maintain security of supply on Bornholm, Læsø and Anholt, each of which is connected to the rest of Denmark or to Sweden via one submarine cable [277]. These needs are estimated for 2021 at 94 MW, 4 MW and 1 MW respectively [278]. In principle, such reserve supply services are provided by the market, but Energinet indicated that it had already contacted the suppliers of each island and concluded the necessary supply agreements, therefore questioning the reality of such market [279]. In any case, if such services are to be offered, their providers must be able to supply the islands with electricity throughout the period when the submarine cable is out of service. In addition, they must be able to start up from a voltage-free electricity network, energise the local electricity transmission networks and all electricity consumers on the islands [280]. It seems possible that well-designed microgrids could be able to provide such services to these islands. In fact, these islands are technically forming microgrids, as they have to be ready to be islanded. The only element they are missing is the legal recognition of this capability and the possibility to provide services to external grid operators, including through voluntary islanding, for example as part of a load-shedding scheme.

When microgrids are in grid-connected mode, they can offer various flexibility services. However, they then are submitted to the same odds as other flexibility providers. A report released in late 2020 indicates that the "main role for prosumers in Denmark is self-consumption and on-site optimisation" due to the facts that electricity prices are high while the "use of flexibility is limited due to several barriers for independent aggregation"[281]. Selling flexibility services is apparently "only possible through pilot projects" for small and medium-sized providers, while large providers can offer these to balancing markets, also through aggregation. Only industrial players can provide balancing services on their own and also access interruptible load schemes [282]. Consequently, it seems difficult for potential community microgrids to leverage their flexible resources in order to ensure profitability. The following paragraphs do not suggest otherwise.

As indicated in section 3.2, network codes and especially guidelines sometimes need TCMs to be implemented at national level. The EB GL is interesting in this regard as its TCMs could potentially impact the provision of electricity balancing service by many actors, including microgrids, for example when a 1 MW minimum bid size is required.

Tender conditions for ancillary services are defined annually by Energinet. These tender conditions apply differently to DK1 and DK2. The tender conditions for DK1 apply to primary reserve, automatic Frequency Restoration Reserve (aFRR), manual Frequency Restoration Reserve (mFRR) and properties required to maintain power system stability (consisting primarily of short-circuit power, inertia, reactive reserves and voltage control [283]). Alternatively, the tender conditions for DK2 apply to fast frequency reserve (FFR), frequency-controlled disturbance reserve (FCR-D), frequency-controlled normal operation reserve (FCR-N), aFRR, mFRR and properties required to maintain power system stability [284]. For potential microgrids, this means that their location will not only be important in view of the local network operators, but also to know which tenders they might get access to.

Similar to electricity balancing TCMs presented in section 3.3.2, the tender conditions set the minimum size of the bids, the full response time and other technical requirements shaping the design of the flexibility resources. In this case, if the minimum bid size of the primary reserve and aFRR is also set at 1 MW [285], the threshold for mFRR is placed at 5 MW [286] and at 300 kW for FCR-N, FCR-D and FFR, thus exclusively on DK2 for the latter options [287]. Therefore, it would appear that DK2, purely in terms of minimum size requirements, is more fit for the development of different types of microgrids, including small-scale ones. It should be noted that across Denmark, groups of wind turbines and solar panels cannot submit bids on their own in the various ancillary services markets if they do not include "other types of generation to guarantee supply"[288]. This may represent an advantage for microgrids, which in any case should not rely solely on varying energy sources without flexible resources.

Finally, every year, the Danish TSO must release a document assessing the system needs for the coming year [289]. Energinet published its assessment of system needs for 2021, which also indicates which services are marketed (*markedsgjort*)[290]. Frequency services are marketed and the needs estimated by Energinet for 2021 are indicated in table 9 below.

Table 9: Frequency services needs for 2021 (in MW) [291]

Type of service	aFRR		mFRR		FCR	FCR-D	FCR-N
Area	DK1	DK2	DK1	DK2	DK1	DK2	DK2
Quantity	90	12-30	684	623	20	44	18

It is clear that the localisation of the service provider, in our case a potential microgrid, is of great importance. On the contrary, voltage regulation, reactive power effect compensation and network adequacy services are not yet procured via markets, thus limiting these opportunities [292].

In sum, the perspective for potential microgrids in Denmark to offer ancillary services looks quite bleak, except for industrial microgrids. For community microgrids, minimum size requirements and closed attribution mechanisms (opposite to open schemes) represent major barriers.

4.2.2 Application to Samsø

In deliverable D7.1 it is explained that Samsø is not subject to any specific regulation [293]. However, based on the information above, it is possible to assess how national legislation and regulations would translate into possibilities for the development of potential microgrids on Samsø and for further development of the SMILE activities.

In terms of the legal qualification, it is certainly possible to create a CEC on Samsø that could eventually cover the entire island and aggregate all generation, consumption and flexibility resources. However, such an energy community will not be entitled by the legal regime to manage the grid. If the grid is to be managed locally, then it is possible to set up a local DSO and apply to the competent ministry create a VIU thanks to the "less than 100 000 connected customers" exemption. Yet, this does not solve the temporary islanding issue.

Regarding the sale of ancillary services by Ballen Marina (and up to the entire island), an important criterion is that Samsø is connected to the DK1 electricity market. Therefore, it can only access markets with a minimum bid size of 1 MW. This threshold directly excludes Ballen Marina, which only has a 60 kWp PV plant as generation and a 237 kWh electricity battery (plus some other loads being smartened)[294]. One possibility is to provide the available flexibility capacity to an aggregator, which could itself be installed on the island and be piloted by a local CEC, for instance. However, for the time being self-consumption and minimisation of costs remain the most interesting option for the marina. In the future, if the flexible resources are gathered at a higher level, maybe up to the entire island, then its manager could potentially access the different frequency service markets and any other relevant flexibility market. Conversely, Samsø is unlikely to become one of the two black-start providers for Western Denmark, at least for the foreseeable future, given the very strict requirements mentioned before. Finally, Samsø is also not part of the three islands mentioned in the 2021 service needs assessment document where supply reserves are required, as it has two cables connecting it to mainland. Therefore, there is no real incentive to develop islanding capacity and create a microgrid for the sole reason of ensuring security of supply. The only reason to develop such capacity would be as part of a flexibility service, by undertaking voluntary load-shedding, if a legal reform allows.

4.3 Portugal

As specified in SMILE deliverable D7.1, Madeira's parliamentary and executive branches have a certain degree of autonomy, but the acts of regional institutions still need to be ratified by the central government in Lisbon or sent to the national Parliament, including those on energy topics [295]. Deliverable D7.1 also presents the main energy policy documents for Portugal and Madeira, with ambitious renewable energy targets and imperative energy storage development on the island to balance the grid [296]. Madeira's energy targets are updated with a 2030 goal and, according to a regional decree of December 2020, the island shall at least aim for energy self-sufficiency at medium and long term [297]. The following paragraphs identify elements of the national energy regime that can be useful for the development of microgrids, before turning to the specificities of Madeira Island.

4.3.1 Possibilities for microgrids under Portuguese law

Deliverable D7.1 explains that mainland Portugal has implemented the EU liberalised energy market regime [298]. In 2019, it already transposed important aspects of the 2018 RES-Directive into national law through Decree-Law 162/2019 about self-consumption [299]. As detailed further below, the transposition of the 2019 E-Directive is still mostly missing, while the deadline set in its article 71 has already expired. The only other piece of legislation transposing parts of the 2019 E-Directive we could find is DL 101-D/2020 focusing on energy efficiency for buildings [300]. This situation is confirmed by a document from ERSE (*Entidade Reguladora dos Serviços Energéticos* – the Portuguese NRA) from February 2021 which aggregates the essential energy legislation and does not provide other relevant references [301].

The following paragraphs follow the same logic as the previous sections on the EU and MSs above: (i) definition, (ii) existing legal qualifications useful to microgrids, (iii) islanding in network codes and (iv) harnessing flexibility to provide services.

4.3.1.1 Definition

Microgrids are not defined in the existing Portuguese legislation. The closest notion is the *Micro Rede Isolada* (isolated micro grid), which is the transposition of the micro isolated system from article 2 (27) of the 2009 E-Directive [302]. However, this legal qualification does not correspond to the definition of microgrids used in this report as it refers to an isolated system, not an islanding one. Therefore, if microgrids are to be created, they will have to find another legal qualification.

4.3.1.2 Existing legal qualifications useful to microgrids

In Portugal, the Decree-Law (DL) 29/2006 regulates the production, transport, distribution and supply of electricity. It does not mention microgrids. Therefore, we assessed the existing law in order to see whether there are any provisions that could fulfil the three criteria used in section 3.1: small and local, flexibility use and temporary islanding.

General distribution grid operation rules and the unbundling exemption

Article 36 of the DL 29/2006, in its consolidated version from 2021, transposes in Portuguese Law the principle of legal unbundling for DSOs [303]. Paragraph 8 of the same article transposes the "less than 100000 connected customers" exemption, allowing the possibility to create or maintain a VIU. The text is the same as in the directive each time, but for the last exemption it specifies that unbundling – apart from accounting unbundling – simply does not apply to DSOs under this threshold of connected customers. This should facilitate the existing VIU to continue to act in an integrated manner as there is no need for an authorisation from the ministry or the NRA. Nothing is said about size limits (aside from the total number of connected customers for the exemption to unbundling), localness or the use of flexibility, and islanding is not mentioned.

***Isolated systems, CDS and* redes internas**

With regards to the transposition of the other regimes mentioned in section 3.1: articles 3 (ii) and (uu) of DL 39/2018 provide for isolated systems [304] and article 41-A of the DL 29/2006 transposes the

CDSs. The text is the same as in the directive each time. As with the EU regime, it is not in these regimes that microgrids would find their best fit as they always lack at least the islanding capacity.

In addition to these two legal qualifications, Portuguese law recently included the concept of *rede interna* (internal grid). It is defined by article 2 (aa) of the DL 162/2019 as a grid installed within a delimited space and with geographical contiguity (which can also be translated by proximity), composed of interconnected lines and auxiliary electrical installations used to carry the energy generated by one or more UPACs (units of self-consumption, presented in the next paragraphs) to one or more consumption points associated through self-consumption, and that can have an electrical interconnection with the public grid. In sum, this is a sort of distribution system within a confined space, quite similarly to a CDS but without being destined to industrial or commercial use. Its purpose is to interlink production and consumption to authorise self-consumption within the grid, and self-consumers (including collective self-consumers [305]) have the right to set them up for this purpose [306]. This is confirmed by ERSE's self-consumption regulation, which defines the activity of "self-consumption through an internal grid" as the energy produced by a UPAC and consumed by a load interlinked through an internal grid [307]. It is very interesting to note that in the DL, the connection of the internal grid to the public grid is optional, meaning it is neither an isolated system nor a public-grid-connected system *per se*, and it leaves the option to interpret this as a possibility for an islanding grid. However, this would need to be confirmed and secured by amending the legislation or adopting a regulatory act for this purpose. As it is, the *rede interna* ticks the boxes for the criteria of size and localness, but does not provide elements for or against flexibility – although this can be expected in order to smoothly manage a self-consumption based grid – and is unclear on the possibility of temporarily islanding. Although at this point it is the closest legal qualification to a microgrid, it still is not a real solution.]

Energy communities

Portugal has already implemented a legal regime for individual, domestic or non-domestic self-consumption before the European Commission's Clean Energy Package release. Indeed, DL 153/2014 created *Unidades de Pequena Produção* (UPPs – small production units) and *Unidades de Produção para Autoconsumo* (UPACs – self-consumption units)[308], which have been deployed on Madeira, among other places [309]. In 2019, two Decree-Laws reshaped this legal framework, modifying the characteristics of UPPs [310] and setting a new legal regime for UPACs and *Comunidades de Energia Renovável* (CERs – renewable energy communities) [311]. The H2020 project COMPILE reviewed the legal framework applicable to the CERs [312]. Below we provide the relevant definition and regime for individual and collective self-consumption as well as CERs, before analysing them in light of the criteria identified for qualifying microgrids.

The definition of self-consumption is linked to the notion of UPAC, which itself is defined as one or more production units for self-consumption primarily using RESs and associated with one or more loads, mainly to satisfy its own electricity needs. It can be owned and managed by a third party as long as it is subject to the self-consumer's instructions [313]. In article 2 (e), the Decree-Law defines an individual self-consumer as a final consumer who produces renewable energy for their own consumption and who can store and sell their electricity. For non-domestic self-consumers, these activities must not constitute their principal commercial or professional activity. Articles 2 (f) and 5 (b) consider collective self-consumers as an organised group of two or more self-consumers living in the same building or in flats and houses at close proximity or a group of industrial, commercial or agricultural units and other infrastructures that are located in a defined area and which have UPACs. In a nutshell, self-consumers are the actors, acting alone or as a collective, via the use of UPACs.

Self-consumers have the right to install a UPAC, to establish and operate direct lines when there is no connection to the public grid, or to establish and operate a *rede interna* in order to link the UPAC to a consumption point. They also have the right to consume the electricity they produce and store and deliver the surplus to a third party or the public grid, to trade this surplus through power purchase agreements (PPAs) or via supply activities, to install and operate storage systems linked to a UPAC without being subject to any form of double charges, and a number of other rights [314].

In terms of duties, self-consumers are responsible for the imbalances they could cause in the system (a responsibility they can transfer to another BRP)[315]. Collective self-consumers must approve a set of internal rules and regulations defining, among other topics, the rules for sharing the electricity produced, for the payment of tariffs, for the destination of production surplus, and so on [316]. They must also appoint the collective self-consumption managing entity (*entidade gestora do autoconsumo coletivo* – EGAC), which will be in charge of the operational management as well as the *rede interna*, if one exists [317].

The definition of *Comunidades de Energia Renovável* is in fact very similar to the concept of RECs in the 2018 RES Directive [318] as it contains essentially the same conditions in terms of ownership, legal personality, proximity requirement and primary purpose [319]. The regime for CERs is also almost indiscernible from that for RECs provided in article 22 of the 2018 RES-Directive. In essence, article 19 (4) of the DL 162/2019 authorises CERs to produce, consume, store and sell renewable energy, including through PPAs, to share the produced energy within the community and to access all suitable energy markets both directly or through aggregation in a non-discriminatory manner. CERs are BRPs as well [320]. The regime also states that public authorities must be provided with regulatory and capacity-building support to facilitate and create CERs [321].

At first glance, CERs comply with the first of the three established criteria for microgrids: they are intended for small and local systems. Yet, they are not explicitly authorised to own and operate networks. This is logical as the CER transposes the REC and not the CEC from EU law. It is important to await for the transposition of the 2019 E-Directive as the Portuguese transposition may entitle a CEC to own and operate a network. In the meantime, CERs have two options to try to overcome this situation. First, they might use article 19 (7) (e) of DL 162/2019, stating that they must not be discriminated against when acting as DSOs, thus implying that they can be DSOs in the first place. This option could be exploited together with the “less than 100 000 connected customers” unbundling exemption in order to create a VIU, but it would still require quite heavy administrative management and specific technical knowledge and would therefore probably be reserved to industrial or very large community microgrids. The second option is to use the *rede interna*, as presented earlier in this section. The manager of this network is then legally recognised as the EGAC [322] which would correspond to a CER operating the network. The second criteria for microgrids – the use of flexibility resources – can be deduced from the CERs’ regime given that they are authorised to use energy storage. The third criteria about temporary islanding is, as usual, not fulfilled.

Finally, if CERs have to be made more ‘microgrids-friendly’, a number of issues need to be addressed. First, the aforementioned notion of proximity with regards to CERs is to be determined by the government (via the *Direção-Geral de Energia e Geologia*)[323]. It presupposes a close physical and geographical connection between the project and the participants in the CER and can take into consideration elements such as the transformer station to which the project is connected. Such open criteria do not provide much legal certainty to potential CER participants. A clear distance, for example measured from the connecting transformer station and potentially depending on the area (urban or rural), may be more appropriate. The example of France could be of interest in this regard, with a distance from the shared network connection point of 2 km or 20 km depending on the local context

[324]. Secondly, the registration or licensing requirements are set in article 3 [325]. For installations with an installed capacity of up to 350 W no specific requirements apply and for installations between 350 W and 30 kW, the requirements are limited to a simple communication. Installations between 30 kW and 1 MW need to register and obtain a certificate of exploitation. And the larger ones need production and exploitation licences. The application of these requirements must be checked to verify that they are not used to set undue barriers, especially considering that a 30 kW threshold can quickly be reached, for instance by connecting a pair of standard EVs. Thirdly, CERs have a duty to size their UPAC in a way that production matches consumption as closely as possible [326]. This automatically limits the amount of energy a CER can use to provide ancillary services to system operators, which can be very detrimental to its business plan and to the system itself. CERs should be exempt from this provision.

4.3.1.3 Islanding in network codes

The EU network codes reviewed in section 3.2 directly apply in Portugal and therefore their conclusions vis-à-vis islanding as well. For this study, we assessed various ERSE regulations, including the Regulation on Access to Grid and Interconnections (*Regulamento de Acesso às Redes e às Interligações* – RARI [327]) and the Regulation on Smart Distribution Grid Services (*Regulamento dos Serviços das Redes Inteligentes de distribuição de energia elétrica* – RSRI [328]), but without finding any provisions specifically relevant for temporary islanding. However, other network codes provide elements regarding the possibility for potential microgrids to sell various services to system operators and third parties.

4.3.1.4 Microgrids' participation to flexibility markets

In the following paragraphs, we assess the rules in Portugal for the provision of interruptible load services (provided by microgrids through islanding) and black-start services to the TSO given that these are within the realm of the specific requirements applying to microgrids. Afterwards, we address the opportunities and barriers for microgrids to provide flexibility services to third parties in order to enhance their economic situation.

In Portugal, the regulation on network operation (*Regulamento de Operação das Redes* – ROR) lists the system services that can be provided to system operators [329]. These include interruptible load and black-start services. Article 32 (4) explains that these system services can be remunerated, theoretically providing an economic incentive for microgrids. Such services then have to be contracted in a transparent and non-discriminatory manner and must authorise the participation of producers and consumers [330]. On paper, this a good news for potential microgrids, but the devil is in the details.

First, the regulation on commercial relations (*Regulamento das Relações Comerciais* – RRC) establishes the main principles for the participation of small production units in system services, including interruptible load [331]. The RRC defines interruptible load in article 2 (uu) but refers to the "adequate legislation" and the ROR for its regime [332]. Here, the adequate legislation is in fact Ordinance 592/2010, which sets out the requirements for providing such a service, including a minimum interruptible capacity of 4 MW [333]. In addition, article 319 (3) of the RRC specifies that installations that provide remunerated interruptible load services cannot also offer ancillary services for the same capacity and the same flux (injection into or extraction from the grid). As a result, flexibility owners willing to provide interruptible load services face at least two main barriers: it will be difficult for them to offer 4 MW of interruptible capacity except as part of an aggregator portfolio, and this service severely limits the possibility to diversify the revenue sources. Secondly, the Manual of procedures for the management of the system (*Manual de Procedimentos da Gestão Global do Sistema* – MPGGS) contains technical rules for various ancillary services. However, black-start services (*arranque autónomo*) are not mentioned in this manual nor are they defined and organised in the other consulted documents.

When in grid-connected mode, a microgrid could provide many flexibility services to third parties, therefore acting like an energy community or collective self-consumers. According to a report published at the end of 2020, in Portugal "self-consuming prosumers […] are exempt from paying charges related to energy and economic policies" since 2019 [334]. Nevertheless,

> [e]xplicit use of flexibility is very limited due to regulatory barriers. Only one aggregator, acting as a [BSP] and only as a pilot project, is currently offering aggregated demand services to the ancillary services markets (regulation reserve market). The only other active aggregators are mediating between renewable energy system generators and the day-ahead and intraday markets, acting as [BRPs][335].

Therefore, the main business model available to CERs and collective self-consumption seems to be to achieve savings on electricity costs (especially on grid tariffs). Although such a system can kick-start the development of energy communities in countries with high electricity costs (such as Denmark), it is of limited efficiency when this is not the case and always represents a missed opportunity to leverage local flexibility. An adapted framework for the provision of flexibility services by small and medium-sized actors is therefore needed.

For the provision of ancillary services by potential microgrids, the ROR, mentioned above, is also relevant. Among the ancillary services that can be provided to system operators are frequency and voltage regulation and regulation reserve [336]. However, article 32 (3) specifies that voltage and primary frequency regulation services must be provided by producers for free, thus excluding the creation of a market for these services. Other services, including secondary frequency regulation and regulation reserve can be remunerated [337]. When digging into the application regulations, one can find that Ordinance 41/2017 establishes the remuneration regime for the safety reserve service (a type of frequency service)[338]. The remuneration of such a service is to be determined through a competitive auction [339], yet, article 4 (1) stipulates, that an installed capacity of at least 10 MW is needed to make offers, which imposes a prohibitively high barrier to most potential microgrids. In spite of this, article 4 (3) authorises demand response service providers to present offers relying on aggregation. This may allow potential microgrids to integrate such portfolios, but again they will depend on their aggregator and its conditions. Finally, the earlier mentioned MPGGS contains rules for the regulation reserve [340]. Article 4 of the MPGGS requires the market parties willing to provide regulation reserve to own "balancing areas" (*Áreas de Balanço*), which refers to production or consumption units using pumped hydro storage. This technology requirement greatly limits the participation of potential small and medium-sized service providers, including potential microgrids.

To conclude, the provision of commercial services to third parties by potential microgrids in Portugal looks rather difficult. With regard to their core requirement (temporary islanding and black-start), there is either no established regime or the access barriers are too high. For the more general services such as frequency support and voltage regulation, they are either not remunerated or present minimum size requirements that are incompatible with the expected average capacity offered by a microgrid. Some of these documents apply to Madeira (e.g., the RRC), but not all (e.g., the ROR). Indeed, the island also has its own regulations and its own network code.

4.3.2 Possibilities for microgrids under Madeira's legal regime

As specified in section 3.4.3, Madeira benefits from a derogatory regime from the liberalised electricity market. However, it is not a total exemption, as some norms apply, others have been transposed with minor changes and the role of the national regulator (ERSE) extends to the island too [341]. DL 162/2019, the main Portuguese piece of legislation regarding self-consumption and energy communities, was first partially adapted to Madeira through Order 240/2020 [342]. Later on, DLR 1/2021/M replaced this Order and more thoroughly adapted the national Decree-Law to the Madeiran context [343]. In addition, another essential legal text is the island's grid code, which was adopted on 6th November 2019 [344]. In the following, we apply the same logic as in the previous sections: looking for a definition, for existing legal regimes, for islanding in the network code and for provision of flexibility services.

4.3.2.1 Definition

Neither the DLR 1/2021/M nor Madeira's grid code define microgrids. Therefore, similar to the national level, one must find elements in the existing regime that could allow the development of microgrids.

4.3.2.2 Existing legal qualifications useful to microgrids

The potentially useful legal regimes that could provide a basis for developing microgrids (essentially CERs) have mostly been adapted from the national DL 162/2019 to the regional DLR 1/2021/M with very few changes. Indeed, the definitions of the key terms – such as self-consumption, CER, UPAC, or *rede interna* – are the same [345], the notion of proximity raises the same question [346], the sizing rule of the UPAC did not change [347], and the provisions of the *rede interna* still hold on the island [348], offering the same unclear perspectives of recognising a microgrid as such.

However, a few elements have been amended. The one that reflects Madeira's grid issues the most is article 3 of DLR 1/2021/M about licensing requirements. It provides for different levels of authorisations, varying from a light version for smaller generators to stricter ones for large generators. In this version, the threshold for registering the installation has been lowered from 30 kW to 350 W, with the need for a technical opinion by the DSO and a decision by the Direção Regional da Economia e Transportes Terrestres [349]. Here as well, the licencing rules (the rate of rejection, the reasons invoked, etc.) and their application have to be assessed in order to check whether these provisions do not constitute undue barriers to the connection of small-scale generation – and potentially the development of microgrids. In addition, the regional Decree-Law's transposition of article 19 (7) (e) of DL 162/2019, requiring CERs not to be discriminated against when acting as DSOs, thus implying that they can be DSOs in the first place, and therefore operate a network, was amended. According to article 19 (6) (d) of DLR 1/2021/M, CERs must not be discriminated against when they act as final consumers, self-consumers or electricity suppliers, but the mention of the DSO activity has disappeared. Although there is still the possibility to see a CER managing a *rede interna*, this amendment indicates that the regional legislator is not willing to consider CERs as operating a grid. Finally, the same article 19 of the regional Decree-Law does not include the capacity-building requirement for public authorities to facilitate the development of CERs, unlike the national version.

Therefore, in Madeira as on mainland Portugal, there is no ready-made legal regime for developing microgrids, especially with regards to temporary islanding. It is important to scrutinise the ongoing transposition of the 2019 E-Directive to assess how the concept of CEC will apply to Madeira and whether or not a CEC in Madeira will be authorised to operate a distribution grid.

4.3.2.3 Islanding in the network code

Madeira's network code provides in chapter 12 a series of interesting definitions that could be relevant for developing microgrids, such as consignment (*consignação*), isolation (*isolamento*), blockage (*bloqueio*) and interconnection point (p*onto de interligação*)[350]. The first three ones could be significant to the temporary islanding of a microgrid and the last definition could be considered as the local definition of a PCC. However, there is no definition nor mention of the *rede interna*, nor of the notion of islanding as such. In terms of the regime, the core of the grid code is described in chapter 4, which concerns technical conditions for grid connection. If microgrids would be considered as an option, this chapter would need to be amended to allow for the development of microgrids (i.e., with islanding capacity).

When considering Madeira's network code, it can be noted that articles 4.4.1 and following set out the requirements per installation type, from A-special (less than 2.5 kW) to D (over 5 MW), in a similar way to the EU network code RfG NC (see section 3.2.1). However, it also states that installations of all types must remain connected to the network, apart from specific situations in which the system operator can request it being disconnected (and subsequently authorise reconnection after a lapse of at least 3 minutes and the reestablishment of the voltage back to at least 80% of its normal value)[351]. In addition, all asynchronous generators must integrate automatic disconnection capacity [352]. These anti-islanding measures, which require installation to remain connected or simply getting switched off, have been identified in the literature as one of the main regulatory barriers to microgrids [353].Nevertheless, some of these grid connection/disconnection measures are already close to microgrids-friendly. For example, article 4.3.7 requires that producers disconnect from the grid for technical or security reasons when the grid operator requires it, and for this to happen there must be fast and efficient communication channels between the producer and the system operator. Whereas the communication requirements must be kept as they are, the reasons for disconnection should actually be expanded and be part of a facilitated interruptible load service through islanding. For microgrids to develop, chapter 4 of the grid code should be amended to a certain extent to authorise temporarily islanding grids.

Chapters 5 and 6 of the grid code provide a regime for when a network is confronted with specific situations and some of its parts need to be disconnected to perform grid maintenance. These are actually the chapters that contain the relevant provisions that could be relevant for an islanding regime. These articles may have to be slightly adapted and could, together with the new provisions of chapter 4, create an islanding regime for Madeira.

4.3.2.4 Microgrids' participation to flexibility markets

As mentioned above in section 4.3.1.4, some parts of the national regulation about commercial ancillary services also apply to Madeira, such as the RRC, establishing the main principles for the participation of small production units in system services, including interruptible load. However, others do not, at the image of the ROR, the document that had set the 4 MW minimum threshold for offering interruptible load services.

The local legal and regulatory regime does not add much to the national regime when it comes to selling grid services. The grid code is of no help, except perhaps to an extent through the provisions 4.4.5 about the connection requirements for type C installations (from 1 MW to 5 MW)[354]. Indeed, these PGMs are required to be able to provide frequency support services. The question here is whether microgrids could be considered as production installations, as these would most likely be able to offer frequency regulation, even with less than 1 MW of installed capacity, or if this requirement should be lowered to type B PGMs. An older document dedicated to Madeira, the *Manual de Procedimentos do Acesso e Operação do SEPM*, provides some conditions for offering secondary frequency reserve to EEM [355]. However, among other requirements, this service can only be provided by hydropower or thermal energy generators, therefore not the most appropriate situation for potential microgrids on Madeira. DLR 1/2021/M does not address this topic of ancillary services either, but it provides several relevant elements when it comes to the remuneration of the electricity sold by a (collective) self-consumer (including a CER) to the supplier of last resort, which is automatically EEM on Madeira [356]. In this case, the kWh price paid by EEM to the self-consumer is equal to 90% of its market value, as defined in Order 240/2020 [357]. The idea is to incentivise the self-consumers to sell their electricity directly on the market or through a PPA instead of selling to the obliged buyer.

Overall, the situation for potential microgrids on Madeira is still quite complex. They can use the legal qualification of CERs, but they do not have a secure legal regime to temporarily island and lack access to flexibility markets, which may be needed to ensure the economic viability of such a project. Actually, EEM intends to directly provide for most of the flexibility needs through large batteries and pumped hydro storage. Other actors could provide some more local services such as voltage regulation, but there is no market for these services yet.

4.4 Relevant cases on other islands in the EU

In order to gather more data on microgrids and on their legal frameworks in other EU MSs with islands, we checked (i) the results of the Interreg project *Pegasus* and (ii) we prepared a questionnaire together with DAFNI.

The Interreg project *Pegasus* focused on the development of small grids that possibly could be considered as microgrids in seven locations [358]. According to their description, at least two of them are capable of islanding: one in Greece and one in Malta. It is unclear from the project results whether any particular legal framework was in place to favour such developments [359].

Regarding the questionnaire, we received answers from Cyprus, Denmark (although also a part of SMILE), Greece and Spain. We asked the respondents for information on any legal regime that would authorise the development of microgrids and for examples of existing microgrids or assimilated systems on their territory. In Cyprus, the case of a university campus microgrid was mentioned, with real-time management and a connection to the public grid, but without more information. In Greece, the island of Tilos was mentioned. This island is connected to the Kos-Kalymnos autonomous electrical system via a submarine cable, but it can operate in islanded mode, especially to avoid issues with the cable. Renewable energy and energy storage units are installed, working together with electromobility under a real-time management platform, meeting the energy needs of the island's 780 inhabitants as well as those of the tourists during the summer months and offering ancillary services to the system. Finally, in the case of Denmark, the island of Bornholm was presented. As explained in section 4.2.1.4, Bornholm is connected to Sweden via a submarine cable but can get islanded in order to maintain supply. The low- and medium-voltage grid of the island connects 30 MW of wind power, 16 MW of combined heat and power, demand response resources and EVs. In total, Bornholm represents a population of 40 000 with a peak power demand of approximately 50 MW. In light of the legal framework in Denmark, Bornholm can be technically considered as a large microgrid with a sizeable potential for the provision of flexibility services to the rest of the grid. The results of the questionnaire show that none of these countries has legally defined nor regulated microgrids.

4.5 Summary

This chapter has analysed the relevant legal regimes in the SMILE countries: the UK, Denmark and Portugal. Similar to the EU level, none of these legal frameworks defines microgrids. Following the same methodology as in chapter 3, this chapter used the three identified criteria for a legal definition of microgrid: it fulfils the requirement that the network is local and/or of a small size, it must use flexibility resources and it must be capable of temporary islanding. Then, these three criteria were applied to existing national regimes, i.e. the general distribution grid operation rules, the "less than 100 000 connected customers" exemption, isolated systems, CDSs, energy communities and sometimes a specific type of network (e.g. private wire network or *rede interna*).

The first result of this research into national legal regimes is that none allows for developing microgrids. In particular, voluntary temporary islanding is always an issue. The second result is that energy communities in EU MS (Denmark and Portugal) meet most of the requirements for becoming a microgrid, under the condition of a few amendments. Indeed, Denmark excludes them from grid operation and Portugal has only transposed the REC, which does not grant any clear authorisation to manage distribution networks. In the UK, the results differ due to the Brexit.

In the table below, we summarise the outcome and recommendations of this chapter. The table contains four columns, one for each of the three national legal regimes and a separate one for Madeira, given it has its own legislation and network codes.

Table 10: Outcomes of chapter 4, per country (and with Madeira island)

	UK	Denmark	Portugal	Madeira
Are microgrids legally defined?	No	No	No	No
Which existing legal qualification comes close to the concept of microgrids and why?	VIU created with Class Exemption Order and declared community energy project. It fulfils the smallness and (potentially) the flexibility criteria	CEC. It fulfils the localness and flexibility criteria	REC operating a *rede interna*. It fulfils the localness and (potentially) flexibility criteria	REC operating a *rede interna*. It fulfils the localness and (potentially) flexibility criteria
Are there any criteria that need to be met in order to develop microgrids?	Voluntary temporary islanding	(i) CEC is prohibited to own and operate its own grid, (ii) voluntary temporary islanding	(i) REC is not explicitly allowed to own and operate its own grid. This may change following transposition of CEC in Portuguese law, (ii) voluntary temporary islanding	(i) REC is not explicitly allowed to own and operate its own grid. This may change following transposition of CEC in Madeiran law, (ii) voluntary temporary islanding

	UK	Denmark	Portugal	Madeira
Is voluntary islanding considered in network codes?	Only in case of outage and if agreed with the DSO beforehand	(i) Only in case of fault and undesired (ii) limited to type D PGMs	Not as far as we know	Not voluntarily, only in case of grid maintenance
What is needed for microgrids' islanding?	Authorise voluntary temporary islanding	Authorise lower PGMs to undertake voluntary islanding	Authorise voluntary temporary islanding	Extend the existing conditions to voluntary temporary islanding
Can potential microgrids offer ancillary services (black-start, balancing, etc.) to TSOs and DSOs under the current framework?	No, the threshold is too high (often type C PGMs at least) except for industrial microgrids	No, the threshold is too high (i) technically (black-start services) or (ii) in terms of minimum bid size (mostly 1 MW for balancing) except for industrial microgrids	No, (i) various services are not marketed or (ii) high access requirements (e.g. 4 MW minimum bid size) except for industrial microgrids	No, basically no ancillary markets
What is needed for potential microgrids to access these markets?	Authorise willing type B PGMs and small power stations to provide ancillary services	Authorise willing type B PGMs to provide ancillary services by lowering access requirements (e.g. min. bid size at 300 kW as in DK2)	(i) Open more services to all relevant providers (ii) lower the access requirements	Creation of ancillary services markets, at least for small local services (e.g., voltage regulation)

In addition to table 10, we present in a few paragraphs the situation of the SMILE islands and SMILE technologies *vis-à-vis* the development of microgrids. All three SMILE islands present great potential for the development of energy communities, or in the case of the UK, community energy projects. With regard to the development of microgrids, the situation is more nuanced. There is often potential, but there are more barriers. These barriers are legal but also technical. The SMILE technologies could offer solutions at the condition of being designed for voluntary temporary islanding.

In Orkney, it may be possible to group the flexibility offered by the SMILE technologies in one of the ANM zones and bundle it under a single license-exempt operator cumulating distribution, supply and generation. Alternatively, all isles could potentially jointly form a single microgrid, if more flexible resources are integrated. As a first step towards creating a microgrid, it may be possible to create power islands for in case of outages, depending on negotiations with the local DSO: SSEN.

In Samsø, Ballen Marina can most likely be considered as an active customer. In the future, it may even be possible to establish a CEC that could include up to the entire island, aggregating all available generation, consumption and flexibility resources. However, such an energy community would not be entitled to manage the grid. As Samsø is connected to DK1 (Western Denmark bidding zone), it can only access markets with a minimum bid size of 1 MW, which directly excludes Ballen Marina, except through aggregation. In the future, if flexible resources would be gathered at island level, the flexibility manager may potentially access the relevant markets for ancillary services. Overall, Samsø is the most advanced island to implement many of the new EU and national regimes for local, small-scale energy actors and use the flexibility activities they can offer, except for the very islanding capacity that is a key element of being a microgrid.

The situation of Madeira is very specific because of its size and distance from mainland Portugal. To facilitate the development of microgrids, the island's network code could be amended and modify some of its existing provisions relating to grid maintenance in order to allow islanding following an agreement with EEM, the grid operator. The code must also be amended to authorise medium-sized generators as potential market participants in case these wish to be considered as such. In addition, local markets for ancillary services should be created and opened to small and medium-size generators to participate in the market in case they so wish. All in all, Madeira would greatly benefit from services offered by microgrids and thus to achieve the required energy transition, but paradoxically, this island is where barriers are the greatest.

Last but not least, we gathered data about legal frameworks for microgrids from several other EU countries, but none had legally defined microgrids nor provided them with a regime.

5 Conclusions and recommendations

This deliverable presents an in-depth study of the concept of microgrids, their potential development under the current legal framework at EU and national level and their possible use on the SMILE islands, leveraging the SMILE technologies. Microgrids may prove to be a key element of the transition to a decarbonised energy system. Whether or not microgrids will take this potential role is a techno-economic question rather than a legal one. The law, however, can facilitate the development of microgrids if policy-makers envisage there is a need to introduce such a new concept in the overall energy system. This study therefore examines this concept more closely. Various conclusions can be drawn from this work.

First, a literature review regarding the very concept of microgrids has shown that there is no universal definition. Nevertheless, a few principal components can be identified: (i) temporary islanding capacity of the microgrid, (ii) almost mandatory use of flexibility resources to maintain the microgrid's balance and (iii) requirement regarding their small-size and localness. The review has also revealed the importance of differentiating microgrids from other concepts such as smart grids or mini-grids. Additionally, microgrids can be distinguished on the basis of their size, their purpose (e.g., industrial or community) and their centralised or decentralised character, i.e. microgrids operating as a vertically integrated utility (VIU) or in a free-market.

Secondly, the concept of microgrids is not legally defined in EU law or in national law of the SMILE countries: Denmark, Portugal and the UK. However, the entry into force of the 2019 Electricity Directive facilitates the establishment of citizen energy communities (CECs) and the involvement therein of active customers. CECs may prove to be a good basis for developing microgrids, despite the absence of any provisions involving the possibility to be temporary islanded.

Thirdly, the network codes will probably have a major role to play in facilitating the development of microgrids in the EU. Currently, several of these documents already touch upon islanded operation, but almost exclusively for emergency situations and in a very restrictive way. This does not meet the idea that microgrids may on a regular basis and depending on market circumstances be disconnected from the public grid and operate temporarily in an islanded mode before being reconnected again. The network codes also provide several rules governing ancillary services such as black-start or balancing.

Fourthly, the regime needs to provide for incentives to develop microgrids. Access to the market is important for microgrids in order to strengthen their economic rationale. As it stands, various recent reports have highlighted numerous barriers that small and medium-sized actors still face in order to provide such services to grid operators (both TSOs and DSOs). Currently the network codes do not permit potential microgrids to market their flexibility potential in order to improve their economic balance and offer more services to a system that increasingly needs them due to the growth of variable renewable energy sources. It seems that the requirements set by network codes to provide ancillary services are often too strict to allow community microgrids to take part to these markets. Only industrial microgrids may have a chance to be developed and provide services such as black-start or frequency regulation.

At national level, technical rules also create barriers for developing potential microgrids. When temporary islanding is mentioned in these documents, it is only in relation to outage or grid maintenance and as a result of an undesirable situation. Voluntary disconnection, islanded operation and reconnection is not really an option. For many types of ancillary services (e.g., black-start or balancing), size is most often a core issue. Indeed, the minimum size requirement to offer such services is often 1 MW, when not directly 10 or 30 MW. Some exceptions exist, such as a pair of frequency service markets in Eastern Denmark with a minimum bid size set at 300 kW. Therefore, at national level too community microgrids lack economic opportunities while industrial ones might be able to access all relevant flexibility markets.

The situation on the SMILE islands (Orkney, Samsø and Madeira) follows the national pattern except for two elements. First, these islands do not have large volumes of industrial loads nor large populations (save for Madeira). This implies that they can mostly count on developing community, commercial or mixed microgrids, possibly encompassing the full island. Yet, even in these cases, they will struggle to gather enough flexibility resources to secure islanded operations and to engage in activities other than self-consumption or energy arbitrage. Secondly, the case of Madeira differs in many ways from the other islands, in particular due to the fact that it has its own legal regime. Because of its lack of interconnection with the mainland and its larger population than on Orkney and Samsø, the island's system is still managed by a VIU and the decarbonisation process is taking more time. The general regime on the island follows the national legal regime in terms of actors, with the recent adoption of a regime governing renewable energy communities, and in that it does not authorise voluntary islanding. Moreover, a market for ancillary services is almost non-existent and will probably not be developed in the medium-term given that the system operator, EEM, is investing into its own large-scale flexibility resources. Yet, there might be some opportunities to support the low voltage network through home batteries, EV smart charging and EV-to-grid in the future, including through the use of the SMILE technologies. If adequately designed, these technologies could allow to provide the necessary flexibility to operate as a potential microgrid.

Considering the above, we make the following legal recommendations with regards to the concept of microgrids.

Consider integrating microgrids into EU law

If the EU wants to introduce the concept of microgrids, it will require a legal definition. We foresee two options.

Option 1: Define microgrids in EU law.
This could be done under the term "microgrid", but a good alternative would be "temporarily islanding network". Where the first term may suggest a small-scale network permanently isolated or grid-connected, the latter avoids this confusion and directly emphasises the key capability of the grid: disconnection, temporary islanding and reconnection. The legal definition should be based on the main elements from the technical definitions and fulfil three criteria:

- Microgrids are local and/or rather small-scale networks. This requirement can be 'translated' legally by putting a cap on the installed capacity or on the number of connected customers.
- Microgrids use flexibility technologies (e.g., storage, demand response, etc.) to remain balanced in all situations.
- Microgrids can operate in islanded mode, i.e. they can voluntarily disconnect, operate in an islanded mode for a specific period of time and then be reconnected and resynchronised with the public grid.

Option 2: Use energy communities as a proxy.
Although EU law contains various legal possibilities to provide limited groups of customers a specific status and/or treat parts of the energy system differently with regard to unbundling requirements, we find that renewable energy communities (RECs) and especially CECs could be used as a basis for further developing microgrids. Yet, in that case they need to be amended in two regards. First, by contrast to the 2019 E-Directive the law should always give CECs the opportunity to own and operate a grid,

meaning that EU Member States should not in their national laws prohibit it, as Denmark has done. Secondly, the directive must facilitate that microgrids may voluntarily operate in temporarily islanded mode.

Irrespective of the option chosen, the E-Directive would need to be amended in order to define the concept of microgrids and its regulatory regime.

Requirements for a legal regime governing microgrids in the EU

It is not sufficient that microgrids are defined in the E-Directive. They also need a specific regulatory regime. It is thus not sufficient to amend the E-Directive but in addition also the 2019 Electricity Regulation and the network codes need to be amended.

This new regime must guarantee three elements. First, although microgrids can be operated in a free-market and with a legally unbundled DSO, we envisage that microgrids will be easier to develop in a regime based on a VIU that will take care of generation, distribution grids and supply. Secondly, the regime must explicitly allow microgrids to voluntarily switch to islanded mode, outside of emergency situations and subject to an agreement with the connecting network operator (in most cases a DSO). Thirdly, microgrids must be recognised as market actors that are able to provide ancillary services in the appropriate markets (e.g., balancing markets).

If microgrids will be introduced in the EU, it will be necessary to fulfil all key requirements of microgrids and particularly temporary islanding. This requires that the EU network codes must facilitate voluntary and temporary islanding (e.g., to provide load-shedding) and extend the black-start and islanded operation capability rules from large generators to medium ones, as an option to be decided by the owner, so that community microgrids can also engage in these activities. This implies a regime regarding reconnection and re-synchronisation rules as well as the conciliation of fault-ride-through and islanded operation.

Last but not least network codes also are relevant to ensure that microgrids can offer ancillary services, which will be an important incentive. Network codes would need to be reassessed in order to determine whether microgrids should be considered as power generating facilities, power generating modules, defence service providers, restoration service providers, reserve-providing units, reserve-providing groups (for multi-microgrids) or balancing service providers. Moreover, can these roles be combined and if so, how? In addition, the documents detailing the application of some of the network codes – especially guidelines – should also be changed in order to provide small and medium-sized actors access to markets for ancillary services. For example, the minimum bid quantity on EU balancing markets (1 MW) as set by the TCMs is too high for microgrids.

In general, it is important to maintain a holistic view of the different codes and to integrate the codes' cross-effects if and when microgrids are included.

Assessment of microgrids under national law

At the moment the concept of microgrids does not exist in the UK, Denmark and Portugal. Moreover, the current legal regimes and legislative possibilities differ in the UK on the one hand and in Denmark and Portugal on the other hand. Based on our legal assessment we conclude that:

In post-Brexit **UK**, the best option for setting up 'community microgrids' is to use the 2001 Class Exemptions Order exempting generators, distributors and suppliers below certain thresholds from having a license. This will allow them, if they so wish, to own and operate a microgrid as a VIU. This approach can be combined with the principle included in the 2006 Climate Change and Sustainable Energy Act that a community energy project may benefit from advice from the government. The main unsolved issues are the possibility of temporarily islanding the grid and how the microgrids could be given access to the ancillary service markets. Supportive legal instruments will have to be incorporated in the network codes.

Amendments to the UK Grid Code will be necessary in order to achieve that microgrids can be voluntary and temporarily islanded. It should provide that microgrids could be considered as small power stations and to allow medium-sized generators and small power stations to offer flexibility services to system operators – including black-start services, which are currently reserved for large generators – possibly through a combination of various sites (a multi-microgrid) that can create and interconnect power islands in case of a black-out. Rules governing market access and product types should be simplified and streamlined, flexibility markets made more transparent and aggregation treated on equal footing with other flexibility services. In addition, the island mode as currently included in the distribution grid connection standard (Engineering Recommendation G99) should be extended to non-emergency situations (of course following the rules set by the DSO to which it is connected), and the DSOs should publish the generally expected requirements for authorising such islanded operation beforehand.

In **Denmark**, CECs could be used as a basis for developing microgrids. However, currently CECs are prohibited from owning and operating networks. The law thus needs to be amended to allow CECs to operate and voluntarily island networks.

The Danish technical conditions set by DSOs consider islanding but only in case of emergency and as such requiring generators to be disconnected. Islanding is thus considered as an undesirable situation. This document will need to be amended to enable voluntary islanding by medium-sized generators – currently limited to generators above 25 MW – subject to conditions of balancing the electricity system.

The Danish transmission system operator (TSO) should assess the possibility of lowering the minimum size requirements for some ancillary products. For example, several frequency services have reasonable size requirements (300 kW), but these are only offered on one part of Denmark (DK2, Eastern Denmark). Also, the threshold for offering black-start services is very high, but we do not recommend to lower this threshold, given the importance of the reliability of these services, unless the TSO would have a reliable alternative via a multi-microgrid provider. The provision of reserve supply to the Danish islands represents an opportunity for well-designed microgrids. It might be an option to develop a pilot project aiming at assessing the use and impact of microgrids on the Danish system.

In **Portugal**, the REC is currently the best option as long as the CEC is not transposed into national law. However, the REC regime says nothing about grid management, even though there is the option for RECs to construct and operate a *rede interna*. However, it remains to be seen whether the transposition of the concept of CEC in Portuguese law will allow them to manage and own an internal grid. In any case, voluntary temporary islanding is currently not provided for in Portuguese law or any technical regulation. In case Portugal wants to develop microgrids, such islanding needs to be achieved, for example via an agreement with the connecting DSO. In addition, a few other specific barriers have to be removed: the notion of proximity to participate in a REC should be determined on the basis of published rules and not be at the discretion of the government, the licensing requirements for generators of 30 kW installed capacity must be checked so as not to create an entry barrier, and the obligation to size the generation plants to meet consumption as closely as possible, which severely limits the potential provision of flexibility services, should be removed as well.

With regards to the provision of ancillary services, the access conditions are too strict for potential small and medium microgrids. For example, a minimum bid size of 4 MW is required for interruptible load services. In addition, regulation reserves are limited to pumped hydro storage, and black-start services are not mentioned in the technical rules. Therefore, markets for ancillary services need to be reassessed.

At national level, the situation regarding the individual SMILE islands differs again between the UK and the EU Member States:

Develop microgrids on the SMILE islands

All three SMILE islands present great potential for the development of energy communities, or in the case of the UK, community energy projects. With regard to the development of microgrids, the situation is more nuanced. There is often potential, but there are more barriers. However, if microgrids are developed on these islands, they could provide very relevant and necessary services to local and/or mainland grid operators.

In Orkney, it may be possible to group the flexibility offered by the SMILE technologies in one of the ANM zones and bundle it under a single license-exempt operator cumulating distribution, supply and generation. Alternatively, all isles could potentially jointly form a single microgrid, if more flexible resources are integrated. As a first step towards creating a microgrid, it may be possible to create power islands for in case of outages, depending on negotiations with the local DSO: SSEN.

In Samsø, Ballen Marina can most likely be considered as an active customer. In the future, it may even be possible to establish a CEC that could include up to the entire island, aggregating all available generation, consumption and flexibility resources. However, such an energy community would not be entitled to manage the grid. As Samsø is connected to DK1 (Western Denmark bidding zone), it can only access markets with a minimum bid size of 1 MW, which directly excludes Ballen Marina, except through aggregation. In the future, if flexible resources would be gathered at island level, the flexibility manager may potentially access the relevant markets for ancillary services. Overall, Samsø is the most advanced island to implement many of the new EU and national regimes for local, small-scale energy actors and use the flexibility activities they can offer, except for the very islanding capacity that is a key element of being a microgrid.

The situation of **Madeira** is very specific as the island has its own regulations and network code. Its regime is fairly similar to that of mainland Portugal and microgrids are not part of it. The REC status has been transposed to Madeira without major changes to the national regime and the provisions of the *rede interna* also apply to the island. Yet, the island’s network code does not authorise voluntary temporary islanding. However, the code could be amended and modify some of its existing provisions relating to grid maintenance in order to facilitate islanding following an agreement with EEM, the grid operator. The code must also be amended to authorise medium-sized generators as potential market participants in case these wish to be considered as such. In addition, local markets for ancillary services should be created and opened to small and medium-size generators to participate in the market in case they so wish. All in all, Madeira would greatly benefit from services offered by microgrids and thus to achieve the required energy transition, but paradoxically, this island is where barriers are the greatest.

This deliverable has been assessing the possibility of introducing microgrids. Although not yet defined in EU law, such development can be relevant as part of the energy transition process. We note that there are still many obstacles in place but the outcome of this study may be worthwhile studying further and to take into account in a next revision of the relevant EU directives and Regulations.

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