**Microgrids and EU Law: Three Models to Solve One Regulatory Puzzle**

*By Jamie Behrendt\**

1. **Introduction**

In the European Union (EU), growing concerns regarding energy availability and the ageing infrastructure of the electricity transmission and distribution networks call for changes in the electricity sector.[[1]](#footnote-1) These changes, technically and legally, must address the climate change related challenges of the electricity sector in the 21st century, which are the reduction of greenhouse gas (GHG) emissions, safeguarding security of electricity supply, and ensuring the competitiveness of the electricity sector.[[2]](#footnote-2)

The electricity grid, as developed in the previous century, is not fully equipped to incorporate the necessary technical changes, in particular when it comes to the integration of decentralised production installations based on intermittent renewable energy sources (RES).[[3]](#footnote-3) RES production is depended on weather and time of the day. This requires balancing, the maintenance of the correct frequency in the electricity system, to provide a reliable supply of electricity.[[4]](#footnote-4) A possibility to facilitate balancing is to ‘include large-scale storage facilities and additional grid connections with enhanced grid capacity’.[[5]](#footnote-5) This would be able to integrate more variable electricity generation sources, which can contribute to reduce GHG emissions, but it would not affect local resiliency needed to safeguard the security of electricity supply.[[6]](#footnote-6) This shifts the attention to smaller scale, decentralised systems, such as microgrids which can facilitate the integration of more RES whilst also creating local energy resiliency.[[7]](#footnote-7) A microgrid is a decentralised grid which can disconnect from the main electricity grid and structure it into ‘local sub-grids that manage their power and energy balancing.’[[8]](#footnote-8) It is a system that has the potential to contribute to tackling the three energy challenges on a local level.

The three main benefits of the integration of microgrids are related to (1) energy security, (2) economic benefits, and (3) integration of RES.[[9]](#footnote-9) In a microgrid, energy security can be increased in a microgrid due to the system’s ability to island itself from the main electricity network. This means that it can function independent of the main network.[[10]](#footnote-10) Secondly, economic benefits refer to infrastructure cost savings, fuel savings, and ancillary services that can be offered by the microgrid.[[11]](#footnote-11) Those services typically include frequency control support, voltage control support, congestion management, and black start services.[[12]](#footnote-12) Thirdly, microgrids can help to reduce GHG by increasing the share of RES in the electricity sector on a local level.

 In the EU, various Member States (MS) implemented pilot microgrids to test the system, such as the Netherlands, Germany, and Greece.[[13]](#footnote-13) However, despite the systems’ potential, a clear legal definition and regulation of microgrids is absent in EU law. This is an issue, as the lack of regulation limits microgrids to unfold their full potential to decarbonise the energy sector.[[14]](#footnote-14)[[15]](#footnote-15)

To support the development of microgrids, the system requires regulatory attention.[[16]](#footnote-16) In earlier work, the integration of microgrids in EU energy law has been analysed by looking at the microgrid as a unified phenomenon.[[17]](#footnote-17) This means that no distinction has been made between various types of microgrids or their technical or organisational structure. This hindered the integration of microgrids in the current EU legal framework.[[18]](#footnote-18)

Considering that each microgrid is tailor-made to a specific location, no microgrid is the same from a technical perspective. However, similarities can be seen when focusing on the organisational structure, which are categorised in literature as three different microgrid models: the DSO Monopoly Model (DSOMM), the Prosumer Consortium (PC), and the Free Market Model (FMM).[[19]](#footnote-19) This paper presents a diversified, functional, approach to the regulation of microgrids focusing on the integration of the microgrid models, as opposed to the technical concept of microgrids, in the EU legal framework.

The central question of this paper is: Whether and to which extent does the existing EU legal framework of the energy sector allow for the implementation of proposed organisational models of microgrids?

This paper will provide the first step towards increased legal certainty for microgrid users and developers by assessing whether and to which extent existing EU energy law allows for sufficient space to develop and operate microgrids. In the following sections, it will first be addressed, from an EU perspective, what is technically understood by the concept of microgrids, followed by an elaboration as to why regulation is necessary. Thereafter, the paper will focus on whether energy law facilitates the development and operation of microgrids.

**2.0 Microgrids from the Technical Perspective**

Microgrids are decentralised electricity systems, which means that they can operate independently of the main electricity network. Carpintero-Rentería et al. mapped the multitude of technical definitions attributed to microgrids and conclude that ‘all share: (a) islanded and grid-connected functionalities; (b) clearly defined electrical boundaries, and (c) a control entity able to manage the energy resources along the loads’.[[20]](#footnote-20) The distinguishing feature of a microgrid, compared to other decentralised energy systems, is the capacity to island itself.[[21]](#footnote-21) Due to the islanding function, which means that the microgrid can cut itself off from the main electricity network,[[22]](#footnote-22) electric loads and small generation systems with loads and energy sources are in close proximity to each other,[[23]](#footnote-23) as well as storage facilities to store produced energy.[[24]](#footnote-24)

To fulfil its functions, microgrids typically include various electricity generation technologies, storage facilities, and smart grid functionalities. The electricity generation technologies can be found in microgrids may range from: Wind power systems, solar photovoltaic (PV) systems, hydropower systems, geothermal energy, biogas, and ocean energy.[[25]](#footnote-25) The four most common sources that are found in microgrids however, are: solar, wind, micro-hydro, and diesel.[[26]](#footnote-26)

Storage devices within a microgrid can ensure that the system will not run out of power, as energy can be saved for later use. This also allows system users to balance the energy demand with its generation. This is particularly useful if the microgrid relies on the renewable electricity sources, considering the volatility of RES. Storage systems implemented so far include batteries and fuel cells (chemical storage systems), superconducting magnetic energy storage (electrical systems), pumped hydro, flywheels as well as compressed energy storage (mechanical systems), and thermal storage in the form of super-heated oil or molten salts.[[27]](#footnote-27) Should the microgrid be connected to a backup supplier, storage facilities are not strictly necessary. However, storage facilities considerably increase the microgrid user’s independence from the main grid. In addition, storage systems can contribute to the economic success of a microgrid, as it supports the option to trade electricity with the main grid.

Finally, smart grid technologies in a microgrid enable a two-way flow of both data and electricity between the microgrid and the main electricity network.[[28]](#footnote-28) This allows the microgrid to offer flexibility services to the main grid but also to manage the electricity distribution within the microgrid. How those technical functions are organised and managed depends on the organisational model, which will be discussed in the following section.

**3.0 Organisational Models**

Depending on the aim behind the implementation of existing microgrids and the location of the system, a general distinction is made between various types of microgrids: commercial microgrids, military microgrids, campus grids, microgrids in remote areas, and community microgrids.[[29]](#footnote-29) Conditional on the microgrid ownership, those types can be further classified into three different microgrid ownership models: the DSOMM, the PC, and the FMM.[[30]](#footnote-30) Those three models are an academic creation, first used by Schwaergerl and Tao.[[31]](#footnote-31) The models are used to categorise existing microgrids based on their ownership structure and has been used by various researchers since.[[32]](#footnote-32)

The first model is the DSOMM in which a centralised distribution system operator (DSO) active in the respective MS, or in a country outside of the EU,[[33]](#footnote-33) also owns and operates the microgrid or appoints a specific, related, DSO for the grid.[[34]](#footnote-34) This DSO is the driving force behind the microgrid’s implementation. DSOMMs are typically built at technically challenging parts of the distribution network (such as remote areas), where it is economically feasible to construct a microgrid (instead of, for instance, extending electricity lines to those areas).[[35]](#footnote-35) This provides the DSO with the additional benefit that the microgrid can be used for flexibility services, which are a range of services that can help to balance the demand and supply of electricity in the electricity network.[[36]](#footnote-36)

The second model, the PC, is run by consumers who both consume and produce their own energy.[[37]](#footnote-37) This can either be a single consumer or a group of consumers. This means that the operator of the system is also part of the legal entity that forms the microgrid. Purpose for the development of such a microgrid can range from decreasing dependence on the centralised grid structure to minimising energy bills or, depending on the regulation, maximising revenue from feeding excess electricity into the central electricity network for remuneration.[[38]](#footnote-38)

The third model is the FMM where the operation and ownership of the grid is managed by any of the stakeholders involved, which could be one of the DSOs of the central electricity grid, the municipality, the electricity supplier, or electricity consumers.[[39]](#footnote-39) In this particular model, the motivation to develop a microgrid differs per project and can vary from economic, to environmental concerns.[[40]](#footnote-40)

Table 1:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| MG Model | Owner  | Purpose | Primary Location  | Primary Financial Stakeholders  |
| DSO Monopoly Model  | Centralised DSO | Economic  | Rural  | Centralised DSO |
| Prosumer Consortium  | Prosumer MG specific DSO | Economic Environmental Independence  | UrbanRural  | Prosumers  |
| Free Market Model  | Centralised DSO MG specific DSO | Economic Environmental Independence | UrbanRural | Centralised DSO/ MG specific DSO, Municipality,Supplier,Consumers |

Those models will also be used in this paper, as it allows this research to be integrated in the existing academic discourse on microgrids and adds to the existing work by focusing on the regulation of the three microgrid models.

1. **Legal Uncertainty and the Need for Regulation**

The development and operation of microgrids is not regulated in EU law. In the academic literature, this is only addressed to a very limited extent. For instance, Attanasio discusses the regulation of microgrids identifying regulatory issues, but without mentioning any specific solutions to the integration of microgrids in the EU legal framwork.[[41]](#footnote-41) In practice, the two reoccurring issues that have hindered the development of microgrids refer to unbundling, and microgrid islanding.[[42]](#footnote-42) Both issues will be addressed in the following section.

3.1 Microgrid Islanding

An islanded microgrid can operate independently from the main electricity grid. In EU energy law, island operation is defined as: ‘[…] the independent operation of a whole network or part of a network that is isolated after being disconnected from the interconnected system […].’[[43]](#footnote-43)

The capacity to island itself allows the microgrid participants to ensure security of supply during a malfunction of the main grid and to enable them to offer ancillary services to system operators of the centralized grid (the connecting DSO, but also a TSO).[[44]](#footnote-44) Ancillary services include, but are not limited to, ‘reactive power and voltage control, frequency responses and supply reserves, and regulation and load following.’[[45]](#footnote-45)

At this point, there is dynamic technical-legal disconnect concerning the islanding function of microgrids: despite the technical possibility to island an electricity system, the current EU regulatory framework does not accommodate for regular voluntary islanding.[[46]](#footnote-46) This is seen as one of the legal elements that hinders the integration of microgrids in the EU energy sector.[[47]](#footnote-47)

 Roggenkamp and Mauger already analysed in detail which changes in the law are needed to facilitate voluntary islanding. The authors focused on the electricity network codes and guidelines that set the common technical framework for electricity grids in the EU.[[48]](#footnote-48) They conclude that the current framework does not facilitate microgrid islanding and that network codes need to be modified. They propose that islanding should:

1. not only be limited to post-black-out situations.
2. They call for the change of technical requirements for islanding so that microgrids can fall under the allowed rules as well.[[49]](#footnote-49)

Furthermore, the authors point out that microgrids need clarity as to the roles of the system can take to support the main electricity network.

3.2 Unbundling

In the EU, the fact that microgrid are not regulated creates considerable legal uncertainty regarding the system’s integration in EU law and the system’s use in the electricity market, as it potentially defies the centralised, unbundled, approach to the production and distribution of electricity.[[50]](#footnote-50)

To enable and protect competition in production and supply activities of electricity, the electricity sector is unbundled. This means that there is separation between the operation of the electricity grid and the competitive commercial activities, like producing and supplying electricity.[[51]](#footnote-51) The Transmission System Operators (TSOs) and DSOs are classified as natural market facilitators who merely manage the grid, whereas the competitive commercial activities regarding electricity production and supply are carried out by third parties. Within a microgrid, there is not necessarily a separation of grid operation and commercial activities, meaning there can be a deviation from the legal organisation of commercial and network activities. In a microgrid, electricity producers and consumers can be directly involved in the management of their own electricity production and consumption, whilst also managing the microgrid.[[52]](#footnote-52)

As microgrids are not regulated, the applicable rules and responsibilities for a possibly bundled system are unclear, which discourages the development of microgrids.[[53]](#footnote-53)This uncertainty can be reduced if microgrids can be regulated under the rules applicable to existing decentralised electricity systems which resemble the microgrid. This analysis has been conducted by Mauger and Roggenkamp.[[54]](#footnote-54) The authors focus on laws relating to closed distribution systems (CDS), energy communities, isolated systems, and the ‘less than 100 000 connected customers’ exemptions for DSOs.[[55]](#footnote-55) These provisions are acknowledged to be the ‘existing EU legal provisions that could serve to set up microgrids with as much legal certainty as possible’.[[56]](#footnote-56)

However, regulating microgrids as a unified phenomenon, without making a distinction between existing microgrids is difficult: A CDS is defined in article 38 of the 2019 Electricity Directive as an electricity distribution system within geographically confined industrial, commercial, or shared service sites.[[57]](#footnote-57) Microgrids do resemble the CDS as both are smaller-scale electricity systems within confined boundaries, but the CDS does not extend to households.[[58]](#footnote-58) This excludes the regulation of microgrids which also include household customers.

Microgrids also share characteristics with both Citizens Energy Communities (CEC) and Renewable Energy Communities (REC), as microgrid users also produce and consume their own electricity or acquire it from a producer within the system. Both energy communities produce and consume electricity within a defined territory with the purpose to grant environmental-, economic- or social community benefits on a non-commercial basis.[[59]](#footnote-59) However, not all microgrids can be considered a CEC or a REC, as for some actors the involvement in a microgrid is a commercial activity.

Furthermore, small isolated systems require a certain energy consumption level ‘of less than 3 000 GWh in the year 1996, where less than 5 % of annual consumption is obtained through interconnection with other systems’,[[60]](#footnote-60) and small connected systems a consumption level ‘of less than 3 000 GWh in the year 1996, where more than 5 % of annual consumption is obtained through interconnection with other systems.’[[61]](#footnote-61) Not all microgrids classify as either of the systems if the energy consumption exceeds the threshold.

As each microgrid differs in its ownership structure and technical set-up,[[62]](#footnote-62) it is not possible to regulate microgrids under one specific set of rules from the EU legal framework. This, however, does not mean that it is impossible to regulate microgrids, it merely indicates that a different approach to the integration of microgrids in the EU legal framework is necessary. One possible approach is to differentiate between existing microgrids by using the three microgrid models mentioned earlier.

**4.0 Regulating Microgrid Models**

In the following section, it will be assessed whether EU energy law can facilitate the regulation of microgrids by integrating the three different microgrid models,the DSOMM, the PC, and the FMM either under the rules applicable to a CDS, or a CEC. Isolated systems will not be included in this analysis, considering the aforementioned limits on energy consumption. RECs will also be excluded as not all microgrids depend on renewable energy only. Considering the characteristics of the three microgrid models (table 1), as well as the CDS and the CEC (table 2), it will be argued that the DSOMM can be regulated under the rules applicable to a CDS, the PC can be regulated as a CEC, and the FMM can be regulated either as a CDS or a CEC, depending on the ownership of the microgrid.

Table 2:

|  |  |  |
| --- | --- | --- |
| Directive 2019/944 | Article 38Closed distribution system | Article 16Citizen energy communities |
| Definition | A system which distributes electricity within a geographically confined industrial, commercial, or shared service 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. | a legal entity that:(a) is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises;(b) has for its 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; and(c) may 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. |
|  Owner | Legal Person | Legal entity effectively controlled by members or shareholders |
| Purpose | To distribute electricity for in areas not connected to the centralised grid for technical or safety reasons, or to distribute distributes electricity primarily to the owner or operator of the system or their related undertakings. | To provide environmental, economic or social community benefits to its members or shareholders |
| Primary Location | Rural areas, industrial sites | Urban or Rural |
| Primary Financial Stakeholders | Centralised DSO | Community Members |

4.1 The DSO Monopoly Model

In this section, in will be argued that EU law can facilitate the development of microgrids if the DSOMM can be regarded as a form of a CDS to which also household customers are connected to, and voluntary grid islanding is allowed. Regulating the DSOMM as a CEC is not possible, considering that CECs need to be effectively controlled by effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises.[[63]](#footnote-63) As the DSOMM is run by a legal person, it will be argued below that the DSOMM should be considered under the provisions governing a CDS.

As a CDS is considered a distribution system, the system operator needs to comply with the unbundling rules applicable to DSOs.[[64]](#footnote-64) In principle, the DSO would not be allowed to produce and sell electricity within a microgrid but should merely manage the grid. However, this requirement can be circumvented when invoking the exemption under the ‘100,000 customers rule’, according to which DSOs serving less than 100,000 customers are exempt from legal and functional unbundling.[[65]](#footnote-65) This allows ‘for a truly integrated entity that owns and operates production, distribution and supply simultaneously’.[[66]](#footnote-66) This rule is particularly interesting for microgrids falling under the DSO monopoly model, as without this exemption, a DSO would not be allowed to manage the microgrid itself.[[67]](#footnote-67) Organising a separate operator in turn increases development costs.

The CDS offers a viable regulatory framework for campus microgrids run by the DSO, as campus microgrids usually do not supply households with electricity. Legal issues only arise if the DSOMM also supplies electricity to household customers. In a CDS, merely incidental use of the system by households is permitted.[[68]](#footnote-68) Considering that the connection to a microgrid is not incidental, this creates a problem as a DSOM that is also connected to households cannot classify as a CDS. There is, however, a solution. With the emergence of CECs, as explained in the previous section, the EU stated that the 2019 Electricity Directive ‘empowers Member States to allow citizen energy communities to become distribution system operators either under the general regime or as ‘closed distribution system operators.’’[[69]](#footnote-69) Hence, if household customers in a CEC may classify their system as CDS, it follows that a DSOMM can classify as a CDS even if it includes household customers. Consequently, the system operator in the DSOMM would be subject to the same rules as a regular distribution system operator, whilst being allowed to supply households with electricity.

* 1. The Prosumer Consortium

Based on the similarities of CECs and the PC as seen table 1 and table 2, it will be argued that EU energy law can facilitate the regulation of the PC under the rules of a CEC, if microgrid users are allowed to take over part of the distribution system and voluntary grid islanding is allowed.

Article 16 of the 2019 Electricity Directive gives MS the discretion to allow CECs to manage part of the distribution networks in their area of operation.[[70]](#footnote-70) This connects to the preface of the Directive, which states that the directive encourages MS to grant CECs the status of a distribution system operator. [[71]](#footnote-71) These provisions can serve as a legal basis for allowing a PC to manage part of the distribution system and become independent from the DSO of the centralised grid.

The 2019 Electricity Directive states that the rights and obligations of stakeholders in an energy community should be in accordance with the roles each party undertakes, i.e., the roles of final customers, producers, suppliers, or distribution system operators.[[72]](#footnote-72) Hence, some members of the community might simultaneously be subject to the rules of a system operator as well as a producer or consumer. However, the customers in the CEC could use of article 15 para 2(d) according to which active customers are entitled to ‘delegate to a third party the management of the installations required for their activities, including installation, operation, data handling and maintenance, without that third party being considered to be an active customer’. The delegated party could be regarded as the operator of the system and the customers in the CEC can take up the role of producer and consumer, which will be managed under the legal provisions of active customers.[[73]](#footnote-73)

Self-consuming active customers, or jointly acting active customers are defined as: ‘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.’[[74]](#footnote-74) As this reflects the possible activities of microgrid users, they should legally qualify as active customers.

Considering microgrid consumers as active customers who are allowed to manage their own distribution system provides the first step to integrating microgrid users in the legal framework. However, the risk of combining the roles of consumer and investor in an electricity system can be demonstrated by the right to switch suppliers, a right granted to energy consumers.[[75]](#footnote-75) In the Schoonschip community in Amsterdam, electricity is produced by 46 houseboats that are connected to their own microgrid.[[76]](#footnote-76) If five members of the community decided to leave, this could not only trigger a power shortage for the remaining parties but would also increase the costs for running the system as additional power needs to be purchased or stored. Consequently, the remaining community members might find themselves in a financial situation that is no longer viable. To adequately protect all microgrid users involved, the contractual obligations must therefore be clearly defined in advance so that no member of the community is negatively influenced by a potential exit of one party from the microgrid. This does not mean that a microgrid user should lose the right to switch suppliers, but it should be contractually determined which microgrid user can make use of this (and other) rights, and which obligations come with joining a microgrid, which is a matter of contract law for which the microgrid users are responsible.

* 1. The Free Market Model

So far, it has been demonstrated that when interpreting the provisions concerning the CDS, energy communities, and active customers, the 2019 Electricity Directive can facilitate the regulation of the DSOMM and the PC. However, the regulation of the FMM proves to be more difficult, as the ownership of the microgrid, the motivation behind the systems construction, and the financial stakeholders involved is dependent on the ownership of the microgrid. In the FMM, ownership can be taken over by either the DSOs of the central electricity grid, the municipality, the electricity supplier, or electricity consumers.[[77]](#footnote-77)

 It will be argued that instead of identifying one regulatory approach for the FMM, the system’s regulatory framework should be assessed on a case-by-case basis. If a legal person is effectively in control of the FMM, such as the centralised DSO, the FMM cannot qualify as a CEC as control must remain with a natural person. In such a case, the FMM could be regulated as a CDS. When assessing whether a FMM should be regulated as a CDS or a CEC, the following chart can be used as a guidance:

Table 3:

|  |  |  |
| --- | --- | --- |
| Microgrid Model | Closed Distribution System  | Citizens Energy Community  |
| DSO Monopoly Model | Tick outline * If electricity household consumers can be connected
* If voluntary islanding is allowed

  | Close outline* The DSMM is not effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises
* The involvement of the DSO constitutes a commercial activity.
 |
| Prosumer Consortium  | Close outline* No, the PC is not a commercial or shared services site
 | Tick outline* If Microgrid Users are considered active customers.
* If voluntary islanding is allowed
 |
| Free Market Model  | Tick outline * If the centralised DSO is involved
* If electricity household consumers can be connected
* If voluntary islanding is allowed
 | Tick outline* If the centralised DSO is not involved
* If Microgrid Users are considered active customers.
* If voluntary islanding is allowed
 |

**Conclusion**

The DSOMM, the PC, and the FMM are models that categorise existing microgrids according to their ownership structure. This article examines whether and to which extent the existing EU legal framework of the energy sector allows for the implementation of proposed organisational models of microgrids. The aim of this paper is increase legal certainty for microgrid users and developers.

Under the current framework, EU energy law cannot the facilitate the development of microgrids, as voluntary grid islanding is not supported in the law. If, however, network codes would be revised following Roggenkamp and Mauger’s proposal, EU law can facilitate the regulation of the three microgrid models if the existing rules allow for some flexibility to include electricity household consumers under the provisions of CDSs and allow for CECs to manage part of the distribution system. This means that microgrids could be seen as a type of a CDS or a CEC, depending on the ownership structure of the microgrid.

This article is one of the few existing legal papers specifically addressing the regulation of microgrids and thus offering a starting point for the integration of the system in EU law. Nevertheless, the approach taken in this article has limitations. This paper leaves out more specific issues, such as balancing responsibilities, or how the microgrid can offer services to the microgrid once voluntary islanding is facilitated. However, those questions only become relevant after the development of microgrids is more advanced. Therefore, the present focus should rather be on creating a more general framework that allows stakeholders to develop microgrids.

1. *\*Jamie Behrendt, LL.M, PhD Candidate in Energy Law, University of Groningen, The Netherlands,* *j.behrendt@rug.nl**.*

 Shabalov et al, ‘The influence of technological changes in energy efficiency on the infrastructure deterioration in the energy sector’ [2021] Energy Reports 2664. [↑](#footnote-ref-1)
2. L’Abbate, et al, ‘Distributed Power Generation in Europe: Technical Issues for Further Integration; European Commission: Luxembourg, in Ali et al, Overview of Current Microgrid Policies, Incentives and Barriers in the European Union, United States and China’ [2017] Sustainability. [↑](#footnote-ref-2)
3. Pinto et al, ‘Power Sharing in Island Microgrids’ [2021] Front. Energy Res. [↑](#footnote-ref-3)
4. Warneryd et al, ‘Unpacking the complexity of community microgrids: A review of institutions’ roles for development of microgrids’ [2020] Renewable and Sustainable Energy Review 121. [↑](#footnote-ref-4)
5. Ibid. [↑](#footnote-ref-5)
6. Ibid. [↑](#footnote-ref-6)
7. Ibid. [↑](#footnote-ref-7)
8. Pinto et al [n 3]. [↑](#footnote-ref-8)
9. Adam Hirsch et al, ‘Microgrids: A review of technologies, key drivers, and outstanding issues’ [2018] Renewable and Sustainable Energy Reviews 402, 405. [↑](#footnote-ref-9)
10. Pinto et al [n 3]. [↑](#footnote-ref-10)
11. Adam Hirsch et al [n 9]. [↑](#footnote-ref-11)
12. Ibid. [↑](#footnote-ref-12)
13. For instance, the Schoonschip Community in the Netherlands, the Microgrid in Mannheim-Wallstadt, and the Kythnos Microgrid in Greece. [↑](#footnote-ref-13)
14. Wouters, Towards a regulatory framework for microgrids—The Singapore Experience’ [2015] 22, 24. [↑](#footnote-ref-14)
15. *This can be confirmed when looking at the development of the Sege Park in Sweden. The only non-solvable barrier encountered in the process of planning a microgrid were regulatory issues. This discourages potential stakeholders and customers to develop a microgrid. In the end, no microgrid was built at Sege Park due to legal barriers, in particular due to the involvement of the DSO.* [↑](#footnote-ref-15)
16. Warneryd et al [4]. [↑](#footnote-ref-16)
17. Mauger, Roggenkamp, ‘Smart Island Energy Systems’ (Deliverable D7.3 Developing Microgrids in the EU, 2021); Attanasio, ‘The regulation of microgrids’ in Roggenkamp et al. (eds), *Energy Law, Climate Change and the Environment* (Elgar Encyclopaedia of Environmental Law, 2021). [↑](#footnote-ref-17)
18. Mauger, Roggenkamp [n 17]. [↑](#footnote-ref-18)
19. Schwaergerl, Tao, ‘The Microgrid Concept’ in Hatziargyriou (eds) *Microgrids: Architectures and Control* (John Wiley & Sons, 2014) 14. [↑](#footnote-ref-19)
20. Miguel Carpintero-Rentería et al, ‘Microgrids Literature Review though a Layers Structure’ [2019] Energies. [↑](#footnote-ref-20)
21. Adam Hirsch et al, ‘Microgrids: A review of technologies, key drivers, and outstanding issues’ [2018] Renewable and Sustainable Energy Reviews 402. [↑](#footnote-ref-21)
22. Pinto et al [n 3]. [↑](#footnote-ref-22)
23. Lopes et al, ‘A view of microgrids’ [2013] WIREs Energy Environ 86, 90. [↑](#footnote-ref-23)
24. Lubna Mariam et al, ‘Microgrids: Architecture, policy and future trends’ [2016] Renewable and Sustainable Energy Review 477, 484. [↑](#footnote-ref-24)
25. Ibid, 481. [↑](#footnote-ref-25)
26. Ibid, 484. [↑](#footnote-ref-26)
27. Ibid. [↑](#footnote-ref-27)
28. I-scoop, ‘Smart grids: electricity networks and the grid in evolution’ (*I-scoop*, 2022) <https://www.i-scoop.eu/industry-4-0/smart-grids-electrical-grid/> accessed 4 May 2022. [↑](#footnote-ref-28)
29. Hassan Farhangi, Geza Joos, *Microgrid Planning and Design - A Concise Guide* (John Wiley & Sons Ltd, 2019) 25. [↑](#footnote-ref-29)
30. Schwaergerl, Tao [n 19]. [↑](#footnote-ref-30)
31. See for instance: Sachs et al, ‘Framing Microgrid Design from a Business and Information Systems Engineering Perspective’ (2019) Business & Information Systems Engineering 729; Soshinskaya et al, ‘Microgrids: Experiences, barriers and success factors’ [2014] Renewable and Sustainable Energy Reviews 659; Li et al, ‘Peer to Peer Smart Energy Distribution Networks’ (D2.2 Regulatory, Business, Technological, and Social Enablers and Barriers of P2P Energy Transfer, 2015); Kaung Si Thu et al, ‘Simulation of Blockchain based Power Trading with Solar Power Prediction in Prosumer Consortium Model’ (International Conference and Utility Exhibition on Energy, Environment and Climate Change (ICUE)*, 2020)).*  [↑](#footnote-ref-31)
32. Schwaergerl, Tao [n 19]. [↑](#footnote-ref-32)
33. *The terminology here is specified to the EU, but the models can also be applied outside of the EU.* [↑](#footnote-ref-33)
34. Schwaergerl, Tao [n 19] 16. [↑](#footnote-ref-34)
35. Ibid. [↑](#footnote-ref-35)
36. EntsoE, ‘Distributed Flexibility and the value of TSO/DSO cooperation’ (Working Paper for fostering active customer participation, 2017). [↑](#footnote-ref-36)
37. Schwaergerl, Tao [n 19] 16. [↑](#footnote-ref-37)
38. Ibid. [↑](#footnote-ref-38)
39. Ibid, 17. [↑](#footnote-ref-39)
40. Ibid. [↑](#footnote-ref-40)
41. Attanasio [n 17] 666. [↑](#footnote-ref-41)
42. See, for instance, the microgrid developed by Tauron in Poland: Koschalka, ‘Poland’s first self-sufficient electricity microgrid launched at former coal mine’ (NfP, March 15, 2022) <<https://notesfrompoland.com/2022/03/14/polands-first-self-sufficient-electricity-microgrid-launched-at-former-coal-mine/>> accessed 19 April 2022; and Sege Park in Sweden: Kojonsaari, Palm, ‘Distributed Energy Systems and Energy Communities Under Negotiation’ [2021] Technology and Economics of Smart Grids and Sustainable Energy 1, 8. [↑](#footnote-ref-42)
43. Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection for generators [2016] OJ L112, art 2 para 43. [↑](#footnote-ref-43)
44. Mauger, Roggenkamp [n 17] 30. [↑](#footnote-ref-44)
45. João Abel Peças Lopes et al [n 22] 96. [↑](#footnote-ref-45)
46. Mauger, Roggenkamp [n 17] 34. [↑](#footnote-ref-46)
47. Ibid. [↑](#footnote-ref-47)
48. Ibid, 31. [↑](#footnote-ref-48)
49. Ibid, 34. [↑](#footnote-ref-49)
50. Soshinskaya et al [n 31]. [↑](#footnote-ref-50)
51. Pollitt, ‘Vertical Unbundling in the EU Electricity Sector’ [2007] Intereconomics 292. [↑](#footnote-ref-51)
52. Trivedi et al, ‘Community-Based Microgrids: Literature Review and Pathways to Decarbonise the Local Electricity Network’ [2022] Energies, 2. [↑](#footnote-ref-52)
53. Kojonsaari, Palm, ‘Distributed Energy Systems and Energy Communities Under Negotiation’ [2021] Technology and Economics of Smart Grids and Sustainable Energy 1, 8. [↑](#footnote-ref-53)
54. Mauger, Roggenkamp [n 17]. [↑](#footnote-ref-54)
55. Ibid. [↑](#footnote-ref-55)
56. Ibid. [↑](#footnote-ref-56)
57. Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU [2019] OJ L 158/125, art 38 para 1, 2. [↑](#footnote-ref-57)
58. Ibid, art 38. [↑](#footnote-ref-58)
59. Council Directive (EU) 2018/2001, art 22; Directive (EU) 2019/944, 16. [↑](#footnote-ref-59)
60. Directive (EU) 2019/944 [n 57] art 2. [↑](#footnote-ref-60)
61. Ibid. [↑](#footnote-ref-61)
62. *Considering that each microgrid is tailor-made to a specific location, to the needs of the stakeholders, and to the aim behind the system’s construction.* [↑](#footnote-ref-62)
63. Directive (EU) 2019/944 [n 57] art 2 para 11. [↑](#footnote-ref-63)
64. Ibid. [↑](#footnote-ref-64)
65. Ibid, 35 para 4 [↑](#footnote-ref-65)
66. Mauger, Roggenkamp [n 17] 25. [↑](#footnote-ref-66)
67. Ibid. [↑](#footnote-ref-67)
68. Directive (EU) 2019/944 [n 56] art 38. [↑](#footnote-ref-68)
69. Ibid, consideration 47. [↑](#footnote-ref-69)
70. Ibid, art 16 para 4 [↑](#footnote-ref-70)
71. Ibid, consideration 47 [↑](#footnote-ref-71)
72. Ibid, consideration 46 [↑](#footnote-ref-72)
73. Ibid, art 2. [↑](#footnote-ref-73)
74. Ibid. [↑](#footnote-ref-74)
75. Ibid, art 12. [↑](#footnote-ref-75)
76. Schoonship Stichting*,* ‘Het Plan’(*Schoonship Amsterdam)* *<*<https://schoonschipamsterdam.org/#het-plan>*>.* [↑](#footnote-ref-76)
77. Schwaergerl, Tao [n 19] 17. [↑](#footnote-ref-77)