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CONCEPT OF MICROGRIDS FROM AN EU LAW PERSPECTIVE

Small Systems: Big Impacts - Examining the Concept of Microgrids from an EU Law Perspective

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Microgrids are generally understood to be localized electricity systems in which electricity is produced and consumed by the users connected to the grid. The system is increasingly considered to be a valuable additional and alternative way of operating the electricity systems across the European Union (EU) and beyond, especially within the context of the energy transition. Yet, in the EU microgrids are not legally defined. The lack of a legal definition creates uncertainty which limits the system's potential to allow consumers to take up a more active role in the electricity sector and diversify the energy sources within the electricity mix. This article analyses the use of microgrids from an EU law perspective, identifying the challenges that will be faced by both regulators and microgrid users. Based on an assessment regarding the purpose, size, operation modes, and supporting qualities of the microgrid, this article ultimately provides a basis for developing a legally valid definition suitable for the EU legal framework.

Keywords: EU law, microgrids, decentralized electricity systems, legal regulation, energy transition

I. Introduction

Microgrids have been discussed as a building block for a more sustainable energy sector.[1] Electricity generation and distribution which is managed independently of the main distribution grid has the potential to positively influence the energy transition towards a sustainable electricity mix.[2] This can be achieved within a microgrid. The stakeholders involved in the construction of the system have the discretion to choose the electricity source, the operation mechanism within the grid and the role of the connected system users (producers and consumers). Yet, the energy sector in the European Union (EU) is subject to considerable regulation, which influences the successful implementation of microgrids. This article explores the concept of microgrids from an EU energy law perspective.

Based on the definition of microgrids established by the US Department of Energy, one of the few actual legal definitions, a microgrid is understood to be a decentralized, interconnected system of loads and energy resources that is capable of meeting the consumer's demand within electrical boundaries that are clearly defined.[3] Additional qualities include the capacity of being isolated from the main grid, storing energy within the boundaries of the microgrid, and offering demand response (DR) mechanisms for both the microgrid users, but potentially also the main distribution grid.[4]

Throughout the EU, the term microgrid is increasingly used in policy documents[5] and research projects.[6] However, no legal definition exists in the EU, which creates uncertainty that hinders the implementation of the system, but also bears the risk of misusing the term as a meaningless 'buzzword'. This lack of legal clarity is also reflected in the academic discourse, which primarily focuses on the technical considerations behind the construction of microgrids. The work of Soshinskaya et al,[7] Hatziargyriou,[8] or Zambroni de Souza and Castilla[9] have contributed to the current technical understanding of microgrids. Yet, to the best of the author's knowledge, no strictly legal literature specifically referring to microgrids exist, except for a few articles such as the study on microgrids in Singapore.[10] Although the absence of a legal definition does not impair the factual existence of what can be considered as microgrids in the EU, the lack of legal certainty does limit the operation and further development thereof.[11] In fact, the absence of a definition means that microgrids are legally non-existent. Hence, electricity consumers in the EU are deprived of the full benefits the system has to offer for society at large, which

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[1] Martin Warneryd et al., *Unpacking the Complexity of Community Microgrids: A Review of Institutions' Roles for Development of Microgrids*, 121 Renewable & Sust. Energy Rev. 1 (2020).

[2] *Ibid.*

[3] 2018 Cal. Legis. Serv. Ch. 566 (S.B. 1339).

[4] *Ibid.*

[5] Pierluigi Mancarella & Danny Pudjianto, *DH1. Microgrid Evolution Roadmap in EU – Final Version*, MORE MICROGRIDS – WPH, Deliverable DH1 (2009).

[6] European Commission, *More Microgrids* (*EC.Europa* 11 Mar. 2020), https://ses.jrc.ec.europa.eu/more-microgrids (accessed 2 Apr. 2020).

[7] Mariya Soshinskaya et al., *Microgrids: Experiences, Barriers and Success Factors*, 40 Renewable & Sust. Energy Rev. 659 (2014).

[8] *Microgrids: Architectures and Control* (Nikos Hatziargyriou eds, John Wiley & Sons 2014).

[9] *Microgrids Design and Implementation* (Antonio Carlos Zambroni de Souza & Miguel Castilla eds, Springer 2019).

[10] Carmen Wouters, *Towards a Regulatory Framework for Microgrids – The Singapore Experience*, 15 Sust. Cities & Soc'y 22 (2015).

[11] *Ibid.*, at 24.

include secure and independent electricity supply, more efficient grid operation, decentral control over the system, and control over the sources of electricity which could lead to increasing renewable electricity sources (RES) in the energy mix.

In the EU, the electricity sector is a liberalized top-down supply – and distribution system.[12] The electricity supply chain commences at the generation facilities. From there, power is being delivered to the end-user via the transmission – and distribution lines that are respectively managed by the transmission system operators (TSO), and the distribution system operators (DSO). The liberalization process of the EU energy sector progressively 'unbundled' activities and control relating to the production and retail are separated from transmission and distribution operation in order to ensure non-discriminatory third-party access to the grid infrastructure.[13] Ideally, this benefits the consumer, who has the right to have electricity supplied by the company of its choice and, due to competition, enjoys lower electricity prices.[14]

Without an EU specific legal definition of a microgrid, it is unclear in how far the departure from the conventional structure is in line with the current regulatory framework on the EU electricity sector, especially EU Directive (EU) 2019/944 on common rules for the internal market for electricity (hereinafter Directive 2019/944).[15] Although this directive does not explicitly mention microgrids, some of the provisions can be linked to the system, such as the provisions on citizen energy communities (CEC), small systems, or closed distribution systems (CDS). Additionally, renewable energy communities (REC), as mentioned in Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, could be linked to the microgrid.[16] Those concepts will be discussed further in the article.

To fill the gap in the current literature, this article primarily focuses on the legal aspects that are relevant for the implementation of microgrids. The structure of the article is inspired by the definition of microgrids that has been adopted by the US Department of Energy, mentioned above. In the following sections dealing with the purpose, size, operation, and additional qualities, each element of the definition will be assessed one by one to examine whether it could align with the EU legal framework. Finally, the article proposes a definition which can form the starting point for further discussing and elaborating the concept of microgrids from an EU energy law perspective.

II. The Purpose of the Microgrid

Microgrids are not a new development. In fact, the very first electricity grids have been micro systems, such as Edison's Pearl Street Station dating back to 1882. Pearl Street Station was an autonomous grid powered by steam engines fired by coal. The station operated with generators that produced 1.100kW direct current, and even included battery storage.[17] The system served several blocks in Manhattan that were in range of the DC network. From 1882, with the sophistication of technology, electricity grids evolved and expanded, and what is understood to be a microgrid has mainly been constructed in remote areas where the central grid could not offer secure and reliable electricity supply. Hence, historically, electricity grids have been constructed for the mere purpose of providing electricity, notwithstanding the size of the grid or power source.[18]

2.1 The relevance of the purpose

In the course of the energy transition towards low-carbon energy sources, the concept of the microgrid regains in relevance, as the system can facilitate the implementation of small-scale RES.[19] Is this the purpose of the microgrid? The positive contribution towards the energy transition was not the primary intention of the EU's 'More Microgrid' scheme,[20] the projects objectives rather focused on the technical aspects concerning microgrid implementations, such as the control strategies, and network design etc.[21] Nonetheless, the projects supported under this scheme do mainly rely on electricity from RES.[22] Although increasing the share of RES was not included in the projects objective,[23] the voluntary

[12] José Sanz et al., *Analysis of European Policies and Incentives for Microgrids*, ICREPQ 1 (2014).
[13] Philip Lowe et al., *Effective Unbundling of Energy Transmission Networks: Lessons from the Energy Sector Inquiry*, EC Competition Pol'y Newsl. 23, 24 (2007).
[14] 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, preamble, 2.
[15] *Ibid.*
[16] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 Dec. 2018 on the promotion of the use of energy from renewable sources [2018] OJ L 328/82, Art. 2, para. 16.
[17] Gene Wolf, *A Short History: The Microgrid*, T&DWord (Overland Park 24 Oct. 2017).
[18] Alamgir Hossain et al., *Evolution of Microgrids with Converter-interfaced Generations: Challenges and Opportunities,* Electrical Power & Energy Systems 160, 162 (2019).
[19] ABB, *Integrating High Levels of Renewables into Microgrids: Opportunities, Challenges and Strategies – A GTM Research White Paper*, GTM Research 3 (2017).
[20] More Microgrids is an initiative that aims to test microgrid architectures and control options of such systems.
[21] European Commission, *Advanced Architectures and Control Concepts for More Microgrids – MORE MICROGRIDS* (Cordis EU Research Results, 20 June 2011), https://cordis.europa.eu/project/id/19864 (accessed 10 May 2020).
[22] European Commission, *supra* n. 6.
[23] The exact objectives of the project include the following: 'Investigation of new micro source, storage and load controllers to provide efficient operation of Microgrids; Development of alternative control strategies (centralized *v.* decentralized); Alternative Network designs; Technical and commercial integration of Multi-Microgrids; Field trials of alternative control and management strategies; Standardization of technical and

adoption thereof by the microgrid users demonstrates that such systems are well equipped for cleaner electricity generation. Yet, not all microgrids include primarily RES. The Manchester University is a partner to the 'More Microgrid project' and its microgrid generates power from both renewable and non-renewable sources.[24]

From a legal perspective, it is relevant to determine the purpose of the system. In order to formulate a precise definition that clarifies all roles and responsibilities of parties within the microgrid, the aim of the system needs to be clear. Only after identifying the purpose, can it be assessed in how far the microgrid may fit into the EU specific rules in the electricity sector.

2.2 Small energy systems under the EU legal framework

Within a microgrid, electricity is generated and distributed amongst consumers, assumedly on a smaller scale than the general distribution system. This purpose is not fulfilled by microgrids only. Besides the main distribution lines, the EU legal framework allows for an exemption of several legal provisions for what is called Closed Distribution System (CDS). A CDS is dedicated to electricity distribution within geographically restricted industrial, commercial, or shared service sites.[25] The definition of the CDS in the 2019 electricity directive thus implies that the purpose of the system is the distribution of electricity within a geographically confined area. In order to fulfil this task, the system operator of a CDS may circumvent administrative and legal burdens, such as the prohibition to own and operate energy storage facilities.[26] However, as a CDS is limited to certain sites, the applicable exemption regime cannot be applied to all microgrids. A CDS explicitly excludes electricity supply to household consumers, whereas the latter system is used for their benefit as well.

To regulate microgrids one could also draw inspiration from the provisions on CEC,[27] or REC.[28] Both 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.[29] CEC's are wider in their scope the definition does not specify a certain electricity source, whereas REC's are exclusively relying on RES and require certain geographical proximity between the shareholders or members and the renewable energy projects.[30] Consumers that utilize the microgrid share certain characteristics with both communities, as the microgrid is also a system in which users produce and consume their own electricity, or acquire it from a producer within the system. However, not all microgrids can be considered a CEC or a REC. For instance, both exclude microgrids in which the members do not form a legal entity or merely involve a single household rather than a community.

The 2019 Electricity Directive also refers to small isolated systems (SIS), and small connected systems (SCS), which are defined as 'any system that had consumption of less than 3.000 GWh in the year 1996'.[31] The distinguishing feature is that the SIS obtains less than 5% of the annual consumption through interconnections with other systems, whereas the SCS obtains more than 5% of annual consumption through interconnection with other systems. Both may also apply for derogations from the legal framework in relation to the tasks of the DSO, the general rules for the TSO, and the unbundling thereof.[32] SIS may also limit the free choice of suppliers, the market based supply prices, and third party access if the European Commission is convinced that there are substantial problems for the operation of the system.[33] Those derogations are limited in time, and set out to eventually increase competition and facilitate the transition towards renewable energy, increased flexibility, energy storage, electromobility and DR [34] Certain microgrids could be classifiable under either of those two systems, depending on the annual consumption as well as the dependence on interconnections. However, the regulator will find itself again in a situation in which not all microgrids classify as either of the systems if they exceed the benchmark criteria mentioned in the definition.

When aligning the microgrid with the US definition, the system cannot be fully regulated under the current EU law regime. Yet, the users of the microgrid may be subject to more legal clarity. Certain microgrid users can be described as active customers, who are defined as a final customer or a group thereof who engages in electricity production or storage within defined boundaries.[35] If purely relying on RES, microgrid users could also be regulated as renewable self-consumers. Those are final customers that produce electricity from RES for own consumption within premises that are located in confined boundaries.[36] If two or more of such final customers within the same building or apartment block join forces to produce and consume electricity, those customers are then considered 'jointly acting renewables self-consumers'.[37] From a legal perspective, those customers remain regulated under the provisions of final customers.[38] Although this does not regulate microgrids directly, the recognition of certain microgrid users as active

commercial protocols and hardware; Impact on power system operation; Impact on the development of electricity network infrastructures'. *See* European Commission, *supra* n. 21.

[24] R. Bayindir et al., *Microgrid Facility at European Union*, ICRERA 1, 5 (2014).
[25] Directive (EU) 2019/944, *supra* n. 14, Art. 38, paras 1, 2.
[26] *Ibid.*, para. 2.
[27] *Ibid.*, Art. 16.
[28] Directive (EU) 2018/2001, *supra* n. 16.
[29] *Ibid.*; Directive (EU) 2019/944, *supra* n. 14, Art. 16.
[30] Directive (EU) 2018/2001, *supra* n. 16.
[31] Directive (EU) 2019/944, *supra* n. 14, Art. 2, paras 42, 43.
[32] *Ibid.*, Art. 66.
[33] *Ibid.*
[34] *Ibid.*
[35] *Ibid.*, Art. 2, para. 8.
[36] Directive (EU) 2018/2001, *supra* n. 16, Art. 2, para. 14.
[37] *Ibid.*, Art. 2, para. 15.
[38] *Ibid.*, Art. 21, para. 2c.

customers can facilitate the operation of the system. Depending on the discretion of Member States, active customers may be granted independence when managing energy communities. However, MS are not obliged to transpose the rights to manage parts of the grids to such communities into national law.[39] Additionally, only a limited number of microgrid users may derive benefits from this as not all customers classify as active customers. For instance, in the microgrid electricity must not always be produced within the direct proximity of a certain household, but a production site can also be shared by multiple microgrid users.

2.3 Determining the purpose

The purpose of the microgrid can be identified when assessing the objective behind the construction of existing microgrids. Common objectives involve economic, technical, and environmental considerations, as well as combinations thereof.[40] Additionally, secure electricity supply is increasingly put forward.[41]

From an economic point of view, the microgrid focuses on the minimization of total costs in both electricity production and consumption in the electricity system.[42] In remote areas, it might be more feasible to construct a microgrid than to expand the distribution lines. This is closely related to technical concerns, as the technical perspective considers the microgrid as a means to optimize network operation by, for example, avoiding power losses.[43]

Nowadays, environmental considerations are vastly addressed too.[44] The establishment of microgrids can be beneficial from an environmental perspective, as the system can enhance the integration of small-scale RES by local production and consumption. The choice for RES within a microgrid allows the system user to curb down emissions and diversify the electricity mix.[45] Solar photovoltaic (PV) systems installed within microgrids are already competitive with diesel generators.[46] The benefit of PV systems is that their costs are falling, and are still subsidized in the EU.[47] Hence, the environmental consideration ties up with the economic incentive.

Finally, secure electricity supply is a motivating factor behind the establishment of some microgrids, as the system can facilitate electricity supply in areas where no energy infrastructure exists.[48] Microgrids do not need to be permanently isolated from the main grid, considering that the system is able to switch from grid-connected mode to islanding mode. The possibility to island itself is seen as a safeguard for security of supply, since the islanded microgrid can still function regardless of a blackout in the main distribution grid. This also increases the resilience of the main grid, as microgrids can support restarting the main electricity grid after a blackout.[49] Especially in the US, this option led to increased implementation of microgrid projects after the 2013 storm Sandy as microgrids prove to be more resilient.[50]

Hence, numerous factors drive the implementation of a microgrid. Depending on the locality of the microgrid, the system aims to fulfil a different purpose. Yet, all driving factors seem to have the same underlying theme, which is electricity supply and consumption that is, to a certain extent, independent of the main distribution network. Why this independence is relevant is unique to each microgrid.

III. Micro: A Misnomer?

The term 'micro' electricity grid implies that one distinct feature of the grid is its size. Based on the name, it can be assumed that the microgrid operates on a small scale, which relates to certain proximity between the grid, system users, producers and consumers. However, it is questionable to what extent the size actually signifies within the context of microgrids, in particular, if one also considers the also undefined terms minigrid or nanogrid.[51] In simple words, what is 'micro'?

3.1 The distribution grid

As inferred from the general understanding of microgrids, it can be assumed that microgrids operate as parallel systems to the main distribution grid. The microgrid functions complementarily, or even independently from the main distribution grid, and is presumed to be smaller than the main national grid. Yet, the size of the distribution grid itself is not fixed either. It is not entirely clear in which relation the grid is deemed to be smaller, considering that the size can relate to the connected capacity, the

[39] Council Directive (EU) 2019/944, *supra* n. 14, Art. 16, para. 4.

[40] Christine Schwaergerl & Liang Tao, *The Microgrid Concept* in Nikos Hatziargyriou eds, *supra* n. 8, at 11.

[41] Amjad Ali et al., *Overview of Current Microgrid Policies, Incentives and Barriers in the European Union, United States and China*, 9 Sustainability 1, 4 (2017).

[42] Schwaergerl & Tao, *supra* n. 40, at 11.

[43] *Ibid.*

[44] *Ibid.*

[45] Adam Hirsch et al., *Microgrids: A Review of Technologies, Key Drivers, and Outstanding Issues,* 90 Renewable & Sust. Energy Rev. 402, 406 (2018).

[46] Cameron Boggon *Solar v. Diesel: Why Solar Generators Should Power Rural Communities* (EKOenergy 21 Jan. 2019), https://bit.ly/3e23cpu (accessed 10 July 2020).

[47] *Ibid.*

[48] Warneryd et al., *supra* n. 1, at 1.

[49] Dough Vine et al., *Microgrid Momentum: Building Efficient, Resilient Power*, C2ES 1, 4 (2017).

[50] Wendy Koch, *Post Sandy, US Pushes Microgrids for Backup Power,* USA Today (McLean Virginia 31 Oct. 2013).

[51] Peter Asmus & Adam Wilson, *Microgrids, Mini-grids, and Nanogrids: An Emerging Energy Access Solution Ecosystem* (Energy Access Practitioner Network 31 July 2017), http://energyaccess.org/news/recent-news/microgrids-mini-grids-and-nanogrids-an-emerging-energy-access-solution-ecosystem/ (accessed 10 July 2020).

number of customers that are connected to the grid, or the geographical scope of the system.

The distribution grid is the lower voltage network that connects the generators to the final household and non-household customers.[52] Within the EU, the organization of the distribution networks differs. Some States regulate their electricity distribution with only a handful DSOs, whereas other states have considerably more. Poland, for example, only has 184 DSOs,[53] while Germany has 883 DSOs.[54] The two countries, which are comparable in terms of size, thus have a remarkably different organization of the distribution network. The contrast in size has no effect on the status of the grid. The many smaller distribution systems in Germany are not less of a distribution system compared to the larger ones in Poland. This demonstrates that the geographical size in itself does not matter, inasmuch as the DSO links the transmission grid with the final customers via the low voltage grid. The fulfilment of a clear purpose, the distribution of electricity for final consumption, is more relevant than size.

Considering that the size of the main distribution grid does not influence its status, it might be assumed that the same applies to the microgrid. After all, the microgrid can be described as a form of localized distribution system. Consequently, microgrids are not necessarily all small. Some microgrids might only connect a few households, whereas other microgrids might sustain an entire village. Rather than mapping the geographical scope of certain grids, other aspects, like the number of connected customers, may be more relevant. In EU law, a certain number of connections, 100.000 customers to be exact, is the threshold for the unbundling rules applicable to the system operator.[55] Hence, microgrids that serve a greater number of consumers might be subject to different access rules to the main grid once regulated on the EU level in comparison to microgrids that serve only a few customers. This difference in treatment is allowed under EU law.[56]

3.2 Microgrid implementations

Heretofore, there is no exact indication of the microgrid's scope. In the various attempts to define the microgrid, scholars have broadly focused on the functions of the grid, yet no consensus on the benchmark criteria concerning size is identifiable.[57] Thus, the size of the grid can merely be assessed on the basis of a literature review as well as the various micro electricity grids that are in place in the EU.

One of the earlier microgrid projects supported by the EU dates back to 2006, to a neighbourhood of 12000 inhabitants within 580 households in Mannheim-Wallstadt in Germany.[58] The project aimed to develop a microgrid that is capable to shift to island mode without an interruption of power supply when the grid switches from grid-connected mode to islanding mode.[59] On-site, the grid developed multiple distributed generation technologies, such as a 4.7 kW fuel cell, a 3.8 kW PV system, a 1.2 kW flywheel storage unit, and two combined heat and power units rated at 9 kW and 5.5 kW.[60] In order to prepare the microgrid, parts of the regular low voltage distribution grid were modified.[61] The modification did not consider a particular size of the grid, but the technical possibilities within the project site. As argued by Rey et al., the estimation of loads is the fundamental issue in the calculation of the size.[62] The size of the microgrid is dependent on the peak power that the loads require, which will in turn influence the volume of the power supply of the generation as well as storage systems of the microgrid.[63]

Another example of a microgrid is the Schoonschip Community in Amsterdam. The forty-seven houseboats of that community are equipped with, in total, 500 PV panels, thirty heat pumps, and battery storage.[64] What is particularly interesting about the Schoonschip community is its continuous expansion. The Community adds floating gardens and shared living spaces that are all connected to the microgrid. This means that the size is not fixed but can continuously develop. Thus, there is currently no maximum on when the grid exceeds the status of being micro. This may blur the line between the larger main distribution network, and the microgrid. It also raises the questions whether the microgrid can factually develop into a distribution system with a similar status as the main network, or whether parts of the main network can turn a microgrid. After all, out of the 880

[52] Directive (EU) 2019/944, *supra* n. 14, Art. 2, paras 28, 29.
[53] Prettico et al., *Distribution System Operators Observatory 2018 – Overview of the Electricity Distribution System in Europe*, Publications Office of the European Union 10 (2019).
[54] A. Breitkopf, *Anzahl der Stromnetzbetreiber in Deutschland in den Jahren 2009 bis 2019* (Statistica 28 Nov. 2019), https://de.statista.com/statistik/daten/studie/152937/umfrage/anzahl-der-stromnetzbetreiber-in-deutschland-seit-2006/ (accessed 4 May 2020).
[55] Directive (EU) 2019/944, *supra* n. 14, Art. 35, at 4.
[56] Case C-439/06 *Sächsisches Staatsministerium für Wirtschaft und Arbeit als Landesregulierungsbehörde, v. Flughafen Leipzig/Halle GmbH, Bundesnetzagentur* [2008] ECR I-3939, para. 42.
[57] Soshinskaya et al., *supra* n. 7, at 661.
[58] D.A.C. Costa et al., *A Survey of State-of-the-Art on Microgrids: Application in Real Time Simulation Environment,* IEEE PES Innovative Smart Grid Technologies Conference 1, 4 (2019).
[59] US Department of Energy, *Mannheim-Wallstadt* (Microgrids at Berkley Lab 2019), https://building-microgribidlbl.gov/mannheim-wallstadt (accessed 18 Mar. 2020).
[60] *Ibid.*
[61] Miriam Khattabi et al., *Advanced Architectures and Control Concepts for MORE MICROGRIDS*, More Microgrids DF5 Report on Field Test for the Transfer between Interconnected and Islanding Mode at the Ecological Settlement in Mannheim-Wallstadt (MVV) 3, 5 (2009).
[62] Juan Rey et al., *Design and Optimal Sizing of Microgrids* in Antonio Carlos Zambroni de Souza & Miguel Castilla eds, *supra* n. 9, at 344.
[63] Mariya Soshinskaya et al., *supra* n. 7, at 661.
[64] Schoonship Stichting, *Wat Is Schoonschip* (Schoonship Amsterdam), https://schoonschipamsterdam.org/#wat-is-schoonschip (accessed 22 Apr. 2020).

DSOs in Germany, 805 serve less than 100.000 customers.[65] From a legal point of view, it is thus important to clarify the status of the microgrid in order to delineate the exact line between the main distribution system and the microgrid.

3.3 The various boundaries

The size of the grid is closely connected to the physical boundaries of the system. Yet, as concluded in the previous section, the size is not set either, but varies. Consequently, the exact boundaries of the microgrid are also unclear.[66] In particular if one considers microgrids as the one in Mannheim-Wallstadt that can switch from islanding-mode to grid-connected mode.[67]

Multiple points can indicate the legal confines of the system. If the microgrid serves an entire neighbourhood with electricity, the boundary could be set by the geographical scope of all the connected households. If the microgrid only serves a single household, one could set the boundaries at the meter of that house. Yet a clearer indication of a boundary can be found in the so-called Point of Common Coupling (PCC).[68] A microgrid that is capable of operation in the grid-connected, as well as the islanding mode will be equipped with a PCC,[69] which is the connection between the main grid and the microgrid.[70] Considering that this point provides a cut between the main – and the microgrid, this point should be considered as the boundary.

Identifying the exact boundaries of the system is relevant, as it could function as a separation mark for the responsibilities of the DSO of the main grid and the microgrid operator. This would mean that the responsibilities that come with the operation of a grid would apply to the operator of the microgrid behind the PCC. In reverse, the DSO is responsible for the management only until the PCC. It is questionable, however, in how far this cut can be made if the microgrid is not islanded. In such a scenario, it remains unclear at which point the microgrid operator and at which point the DSO of the main grid must take up their responsibilities concerning grid management. Legally speaking, this question becomes particularly relevant if either of the two grids is insufficiently maintained with a negative effect on the electricity distribution in the other grid. In order to avoid such a situation, the microgrid operator and the DSO of the main grid must communicate in advance in how far the latter DSO is involved in the management of the microgrid. This communication differs according to the various stakeholders that can be found in the microgrid, as some microgrid models closely work together with the DSO of the main grid, whereas other focus might not involve this DSO at all.[71] In particular for the latter group, the PCC can serve as a clear cut between the microgrid and the main grid, even in grid-connected mode.

IV. The Operation of the Microgrid

The legal framework in the EU regulates the operation of a rather centralized main grid that is run by the DSO. In contrast, microgrid control is typically decentralized and it is not prescribed who controls and operates the system. An assessment of the various control options available to the management of the microgrid will be the focus of the following section.

4.1 Distribution system operation in the liberalized electricity sector

Subsequent to the lengthy process of market liberalization in the EU energy sector, system operators in the EU are subject to a strict unbundling regime. Each component of the energy chain is now separated in terms of control over the respective transmission or distribution lines, which creates a liberalized market for production and supply activities.[72] The grid infrastructure is maintained and controlled by the unbundled TSO and DSO.[73] The DSO needs to comply with the minimum of legal unbundling.[74] This means that the DSO must be independent in its legal form from decision-making, or organization from activities unrelated to distribution, as set out in Article 35 of the 2019 Electricity Directive.[75] However, a DSO connecting less than 100.000 customers may remain bundled, as the unbundling of rather small systems might not always be economically beneficial.[76] Small systems and CDS both fall under this exemption. Considering the similarities between the microgrid and those two systems, it might also be more viable to negotiate the necessary access and operation rules of the microgrid instead of splitting up its organizational structure.

4.2 The legal implications for the operator

The control options in the microgrid depend on the system's mode. If the microgrid is not islanded from the main grid, the microgrid can be, legally speaking, seen as an extension to it and is controlled by the national DSO.[77] The main grid thus influences the electricity supply within the microgrid during the grid-connected mode.[78]

[65] Prettico et al., *supra* n. 53, at 11.
[66] Miguel Carpintero-Rentería et al., *Microgrids Literature Review Through a Layers Structure*, 12 Energies 1, 11 (2019).
[67] US Department of Energy, *Mannheim-Wallstadt* (Microgrids at Berkley Lab 2019), https://building-microgrid.lbl.gov/mannheim-wallstadt (accessed 18 Mar. 2020).
[68] Wouters, *supra* n. 10, at 25.
[69] US Department of Energy, *How Microgrids Work* (Energy. Gov 2014), https://www.energy.gov/articles/how-microgrids-work (accessed 18 May 2020).
[70] *Ibid.*
[71] Schwaergerl & Tao, *supra* n. 40, at 16–18.
[72] Lowe et al., *supra* n. 13.
[73] Council Directive (EU) 2019/944, *supra* n. 14, Arts 35, 43.
[74] *Ibid.*, Art. 35.
[75] *Ibid.*
[76] *Ibid.*, para. 4.
[77] Faisal Badal et al., *A Survey on Control Issues in Renewable Energy Integration and Microgrid*, PCM Springer Open Access J. 1, 9 (2019).
[78] *Ibid.*, at 15.

If the DSO of the main grid controls the microgrid, the DSO's obligation concerning the management of the main grid and treatment of consumers should also apply to the microgrid. For instance, there is no ground to derogate from the non-discrimination obligation to connect system users.[79] The microgrid user should not be restricted in accessing the main grid, unless the main grid operators lack the necessary capacity, for the microgrid users should classify as customers of the main electricity grid.[80] If, however, the microgrid user feeds electricity into main grid as an active customer, the status of those customers may shift to producers. This shift in status results in different legal treatment and the former customer is then subject to the regulation of producers. Amongst others, those producers may have to act in conformity with the balance responsibility in accordance with article 5 of Regulation 2019/943.[81]

Once the system islands itself, the operator of the microgrid may have the sole control. This can be a utility company, a local company, the DSO from the main grid, or the grid owner.[82] The DSO from the main grid should only exercise control over the microgrid if the system reflects the DSO monopoly model, or the liberalized market model that will be elaborated on in the next section.[83] If the DSO of the main grid is not involved, the microgrid specific DSO is not necessarily bundled.[84] This can be of particular relevance if the microgrid involves multiple households, as each connected entity might have different interests in the operation of the grid and use of the electric power.

4.3 Operation options in the microgrid

Different stakeholders engage either physically or financially in a microgrid project. The literature identifies three business models that give insight into the interplay of the various stakeholders in microgrids: the DSO Monopoly Microgrid, the Prosumer Consortium, and the Free Market model.[85]

In the first model, the DSO of the microgrid owns and operates the system as well as the production and supply. The DSO may be and independent entity or owned (directly or indirectly) by the DSO of the main grid subject to internal unbundling. In this microgrid, the DSO would be a vertically integrated utility. [86] From a legal perspective, all relevant provisions applicable to the DSO enshrined in the 2019 Electricity Directive should apply to this microgrid. Consequently, the DSO is fully responsible for 'operating, maintaining and developing under economic conditions a secure, reliable and efficient electricity distribution system' within the microgrid, respecting both the environment as well as the energy efficiency.[87] If the DSO that manages the microgrid is internally separated from the main grid's operation, legal unbundling can be circumvented.

The Prosumer microgrid is fully run by the prosumers themselves who appoint a system operator between them.[88] The DSO of the main grid might have little influence over such a consortium, and can only effectively control it by imposing requirements together with charges when the users of the microgrid wish to trade electricity with the main grid, or seek services thereof.[89] From a regulatory perspective, CECs might facilitate the regulation of such a consortium. If the MS chooses to grant CECs the right to manage distribution systems as microgrids,[90] as for example in the Schoonschip community mentioned previously, the consortium would be able to replace the DSO of the main grid within the boundaries of the community. However, MS are not under an obligation to grant this right to communities, it is the MS discretion to do so, and not all microgrids can classify as CECs.

In the Free Market model, ownership of the resources in the microgrid is split between various stakeholders that might include the electricity generators, the DSO, the electricity suppliers, aggregators, producers, and consumers.[91] The operator of the system tends to be the energy supplier within the microgrid, which can lead to conflicts with the unbundling rules.[92] Although municipalities are not part of the electricity chain, they can also be relevant in the Free Market model. The municipality can considerably influence the construction of microgrids, as seen in the case of MVV. The Free Market model essentially resembles a small-scale version of the main electricity network. It is essentially up to the stakeholders to allocate the responsibilities that come with the operation of the microgrid. Yet, the interplay between the various stakeholders requires high coordination efforts. This can be facilitated, for example, by a technical central controller like the Multi Agent Systems (MAS) used in Mannheim-Wallstadt.[93]

The stakeholders in the microgrid face two control options. It is possible to employ a centralized or decentralized approach.[94] Decentralized control refers to a mechanism in which each controllable element of the

79 Directive (EU) 2019/944, *supra* n. 14, Art. 31.
80 *Ibid.*
81 Regulation (EU) 2019/943 of the European Parliament and of the Council of 4 June 2019 on the international market for electricity (recast) [2019] OJ L 158/54, Art. 5.
82 Warneryd et al., *supra* n. 1, at 7.
83 Badal et al., *supra* n. 77, at 15.
84 Directive (EU) 2019/944, *supra* n. 14, Art. 35.
85 Schwaergerl & Tao, *supra* n. 40, at 16–18.
86 *Ibid.*, at 16.
87 Council Directive (EU) 2019/944, *supra* n. 14, Art. 31.
88 Thomas Sachs et al., *Framing Microgrid Design from a Business and Information Systems Engineering Perspective*, 61 Bus. Inf. Syst. Eng. 729, 736 (2019).
89 Schwaergerl & Tao, *supra* n. 40, at 18.
90 Council Directive (EU) 2019/944, *supra* n. 14, Art. 16.
91 Sachs et al., *supra* n. 88, at 736.
92 Schwaergerl & Tao, *supra* n. 40, at 17.
93 Soshinskaya, *supra* n. 7.
94 Aris Dimeas et al., *Microgrids Control Issues,* in Hatziargyriou eds, *supra* n. 8, at 32.

microgrid can be operated locally.[95] This is facilitated by, for instance, MAS.[96] To a certain extent, the virtual agent is able to take decisions without a central commander. E.g., in Mannheim-Wallstadt, the MAS may decide to start charging a battery if the system indicates that the prices are favourable, and battery charge is needed.[97] The higher the agent's intelligence, the less active involvement of a system operator is required.[98] According to Dimeas et al, this option is particularly useful within a residential microgrid, considering the different electricity needs.[99] Each household can then decide itself if, and when, they need to generate power and what happens with the excess generation.[100] Centralized control, on the other hand, involves one controller who is in charge of all distributed energy resources and local loads as a microgrid central controller.[101] This concept proves to be more suitable for a single owner of the microgrid structure, with a clear goal behind the grid operation.[102]

Although the active involvement of the system operator differs, one party must always take up the legal responsibility for the supervision of control mechanisms and the operation thereof. Additionally, if households within a microgrid have higher autonomy, it must be legally determined if the microgrid has numerous operators that are all responsible for one respective household, or whether there is one party taking up the responsibility of the entire system. This is particularly relevant if parties within the microgrid wish to trade excess electricity, an option available to microgrid users that also enables them to financially profit. Electricity supply and demand must always be balanced,[103] and this trade may cause imbalances that affect both the main grid and the microgrid.

V. The 'Additional' Qualities of the Microgrid

The description of the microgrid presented in the introduction alludes to various qualities that might be included in the microgrid, such as the possibility of switching from grid-connected mode to islanding mode and providing flexibility through energy storage facilities and DR mechanisms. Those functions may not be crucial for the operation of the microgrid but may influence the quality of the overall electricity network. Within this context, the term 'quality' refers to distinctive attributes within the microgrid that benefit the system users in addition to the supply of electricity, such as the possibility to switch grid connection mode or self-sufficiency increasing options.

5.1 Grid-connected and islanded mode

As mentioned throughout this article, microgrids can operate in two modes. The system is either connected to the main distribution grid, or it can be islanded. Depending on the rationale behind the microgrids implementation, islanding might be an additional feature for some microgrids, whereas for others it is a prerequisite.

Predominantly, the option to switch the connection mode of the system only increases the value of the microgrid as this can ensure undisrupted, although sometimes reduced, electricity supply at all times.[104] This increases protection of microgrid users from faults in either system. In areas where the security of supply is the main rationale behind the implementation of the microgrid, the islanding option is therefore crucial. Recalling that the implementation of microgrids increased after storm Sandy,[105] the New York State's microgrid prize competition even required that a microgrid must be able to disconnect from the main grid during extreme weather conditions or emergencies.[106]

Nevertheless, if the microgrid is constructed to increase independence from the central distribution network, the option of being able to connect to the main grid might very well be merely additional. As such, the option to switch connection mode would only be interesting for the microgrid user if such user aims to inject excess electricity produced into the main grid, or if the microgrid needs to undergo maintenance.[107] Similarly, the option to shift between islanding mode or grid connected mode is less relevant for system users that wish to increase the share of RES for a more diverse electricity supply. For those system users, it can be argued that being able to island the system is not the decisive interest, but the control over the source of the electricity that is produced.

5.2 Self-sufficiency

Within the microgrid, the primary goal is to supply electricity to the connected customers.[108] However, if electricity is produced relying on variable RES, production that covers full demand cannot always be ensured.[109] In order to balance both the generation and the load within the

[95] *Ibid.*, at 51.
[96] Khattabi et al., *supra* n. 61, at 17.
[97] *Ibid.*, at 18.
[98] *Ibid.*
[99] Dimeas et al., *supra* n. 94, at 34.
[100] *Ibid.*
[101] Abedalsalam Bani-Ahmed et al., *Reliability Analysis of a Decentralized Microgrid Control Architecture*, IEEE Transactions on Smart Grid 3910, 3911 (2019).
[102] Dimeas et al., *supra* n. 94, at 36.
[103] Reiner A. C. van der Veen & Rudi A. Hakvoort, *The Electricity Balancing Market: Exploring the Design Challenge*, Utilities Pol'y 186, 186 (2016).
[104] Khattabi et al., *supra* n. 61, at 33.
[105] Wendy Koch, *Post Sandy, US Pushes Microgrids for Backup Power*, USA Today (McLean Virginia 31 Oct. 2013).
[106] Warneryd et al., *supra* n. 1, at 5.
[107] Chris Marnay et al., *Lessons Learned from Microgrids Demonstrations Worldwide*, Ernest Orlando Lawrence Berkley National Laboratory 1, 25 (2012).
[108] Hong Du et al., *A Microgrid Energy Management System with Demand Response*, CICED 551, 551 (2014).
[109] *For example, when Relying on Solar Energy, the Sun Is Not Always Shining.*

system, electricity storage facilities within the microgrid can be seen as an important feature.[110] The most commonly used facility is battery storage.[111] The high costs that are associated with electricity storage might explain the optionality of this element. This way, systems in which it is not economically feasible to install storage facilities could still be classified as a microgrid. To circumvent difficulties relating to electricity supply, microgrids that do not have energy storage facilities must resort to back-up generation or electricity from the main distribution network in times of a power shortage.[112] This would, however, necessitate that such a microgrid can operate in the two connection modes discussed previously. Although the availability of storage facilities is not strictly necessary, this option considerably increases the independence of the microgrid user from the main distribution network. Furthermore, storage facilities in the microgrid can also serve as a support storage system for the main grid, as the microgrid operator can trade electricity to the operator of the main grid.[113] In time, this criterion might therefore develop into a main characteristic.

A further element relating to self-sufficiency is DR In the EU, DR is defined as:

> *The change of electricity load by final customers from their normal or current consumption patterns in response to market signals [...].*[114]

This means that within the central grid structure, the system operator might ask the customer to modify consumption patterns in exchange for a financial benefit.[115] In turn, the system operator is able to use the electricity to keep the grid in balance.

DR in the microgrid enables the grid user to alter the consumption pattern within the system more efficiently,[116] which primarily contributes to the users personal benefit and not the main grid operator's. For example, if the microgrid relies on solar panels, the flexible loads, such as washing machines, can be used if the sun is shining.[117] In reverse, on a cloudy day, non-essential loads could be turned off in order to reduce electricity consumption. This mechanism has also been introduced by MVV's microgrid in Mannheim-Wallstadt.[118] DR does not only enhance the microgrids efficient performance, but likewise benefits the main distribution grid. If the microgrid operator sells flexibility to the main grid operator, the microgrid could support the main grid in a similar way as when providing storage services. However, the absence of such mechanisms does not diminish the microgrids function of providing electricity to the grid user and is therefore listed as additional.

VI. The Importance of Legal Clarity

This article assessed the various components that can make up the microgrid. It demonstrates that the rationale behind the development of such a grid, the choice of the operating party, as well as environmental considerations, influence the architecture of the system. As there is no legal definition in EU law that specifies the exact composition of the system, a considerable amount of discretion is left to the project developer. This leads to a situation in which the same term will be used for very different types of systems. For instance, the two systems presented in this article (Mannheim, and Schoonschip) already varied considerably. Furthermore, the lack of a legal definition might discourage the development of microgrids in general. The systems, however, that are developed in the absence of clear rules, might be conflicting with the legal framework that is currently in place in the EU. The main rules for the electricity sector can be found in Directive (EU) 2019/944 as well as Regulation (EU) 2019/943. Although microgrids are not mentioned therein, the rules should still be observed by system operators and users, in particular with regards to the status of the microgrid and the active involvement of the DSO.

6.1 The legal status of the microgrid

There is not one uniform model of a microgrid. The systems vary not only in size, but they are constructed for different purposes, in different areas, involving different actors. Thus, based on the options that are currently available, it is cumbersome to attribute a clear status to the microgrid.

At first impression the microgrid shares quite some similarities with the existing EU legal concepts of CDS, CEC, REC, or small systems. However, as stated previously, a CDS is limited to geographically confined industrial, commercial, or shared service sites.[119] Therefore, the rules applicable to the CDS cannot be extended to microgrids that also benefit households. Furthermore, the detailed description attributed to CES's and REC's could both possibly exclude microgrids that are built for financial advantages, depending how strict the interpretation of financial profits is aligned with the economic consideration. Furthermore, it is questionable in how far those provisions could

[110] Sachs et al., *supra* n. 88, at 734.
[111] *Ibid.*
[112] Asterios Papageorgio et al., *Climate Change Impact of Integrating a Solar Microgrid System Into the Swedish Electricity Grid*, Applied Energy 1, 2 (2020).
[113] Hyeongon Park & Si Young Lee, *Optimal Microgrid Scheduling to Provide Operational Flexibility in Main Grid Operation,* 6 Energy Reports 172, 173 (2019).
[114] Directive 2019/944, *supra* n. 14, Art. 2, para. 20.
[115] Elisa Wood, *More Demand Response in Microgrids Following Supreme Court Decision? Maybe, Maybe Not* (Microgrid Knowledge 19 Feb. 2016), https://microgridknowledge.com/demand-response-in-microgrids (accessed 19 May 2020).
[116] Du et al., *supra* n. 108.
[117] Khattabi et al., *supra* n. 61, at 11.
[118] *Ibid.*, at 4.
[119] *Ibid.*

apply to microgrids that only support a single household, and not a community. The microgrid also cannot be regulated under the provisions applying to SCS or isolated systems, considering that the microgrid can go over the thresholds mentioned in their definitions. This ultimately brings one back to square one at which there is no classification of the microgrid.

The provisions of either the directive or regulation can only serve as guidance as to how such a grid is regulated but cannot fully accommodate the needs of microgrid users. As the status remains ambiguous, the need for a definition is pressing.

6.2 Defining microgrids for EU law

At this point, it has been demonstrated that the current framework leaves gaps or regulatory issues that potentially conflict with the stakeholders' interest in the microgrid operation. This highlights the necessity to reach a uniform definition that is applicable throughout the EU. In order to spark the debate, the following definition is proposed by the author:

1. A microgrid is a system of interconnected loads and production that can operate in grid-connected mode as well as islanding mode, in which electricity is produced, consumed, and possibly stored by the system users for at least one of the following purposes:

a. *to increase independence from the central electricity network*
b. *to secure electricity supply*
c. *to decarbonise the electricity mix*
d. *to make economic profit.*

2. Within the system, the operator may offer demand-response services to both the microgrid users and the operator of the main transmission and distribution lines.
3. The microgrid is controlled by an assigned operator who takes up the legal responsibility for managing the system.

By applying this definition, a variety of systems can be classified as microgrids, regardless of being connected to household customers or to the industry. In addition, the rationale behind the implementation of the system is rather broad to provide flexibility with regards to the future developments of microgrids. It is further stipulated that electricity storage and DR are additional qualities of the grid, which can be profitable for both the microgrid user and the main grid. Finally, this definition makes clear that one party must be the clearly assigned operator, who takes up the responsibility for the operation thereof.

VII. Conclusion and Remarks for Future Research

Based on the current understanding of microgrids, the characteristics regarding the purpose, size, operation, and qualities of the microgrid have been assessed one by one. As a result, it can be said that the implementation of those characteristics differs per microgrid. This may be traced back to the differences in the reliability of the main electricity networks across the globe. Considering that the main grids in the EU are rather advanced, the technical considerations as well as those relating to security of supply are less important in comparison to other regions. Progressing from the primary consideration of simply distributing electricity, the construction of a microgrid in the EU is now incentivized by economic, technical, safety, and environmental considerations. However, the more advanced the main grid is, the more the system can develop into a tool that fine-tunes personal electricity supply.

In terms of size, it can be said that microgrid projects vary in scope and power. The scope of the microgrid is ultimately limited by the technical, as well as financial capabilities of the system instead of a fixed scope. Microgrids also differ in size when assessing the number of customers that are connected to the grid. It can thus be stated that size is not the main defining feature of the microgrid, inasmuch as the grid can operate independently from the main distribution grid to a certain extent.

Considering that the boundaries of the microgrid are influenced by numerous factors, such as the microgrid model that is chosen, the connection mode, and the overall size of the grid, it is also not possible to identify a clear boundary that applies to all microgrids uniformly. From a legal perspective, a clear boundary is necessary in order to be able to attribute the legal responsibilities that are connected with the management of a grid. For this reason, this part suggests making use of the PCC to separate the microgrid from the main grid to provide clarity for the respective system operator.

As there are no limitations on the ownership and the control of the microgrid itself, this article establishes that not all microgrids operate decentral per se. For example, if the microgrid is run by the DSO, it can still be part of the centralized electricity chain. Yet, microgrid users can choose to have a central controller, or a decentralized control system. Generally, this option is not necessarily available to system users of the main distribution system but depends on the discretion of the main DSO.

Finally, as a result of the diverging nature of the system, it is not possible to classify the microgrid under the options that are currently available in the EU framework, such as the small systems, CDS, CEC, or REC. Doing so would limit the potential of the system. From a legal perspective, some aspects of the microgrid may be covered by the existing legal framework, such as microgrids that serve industrial sites and therefore share similarities with a CDS. Yet, microgrids that diverge from those examples are basically in a regulatory black hole. This means that the DSO from the main grid, the operator in the microgrid as well as the connected customers face legal uncertainty on how to regulate the activities within the microgrid. This article, therefore, concludes that further research is needed to clarify the use of microgrids to adequately align it with the EU legal framework. Open questions are in particular who is controlling the microgrid, how the microgrid operator interacts with the DSO of the main grid, and what rights the users of those systems have. To spark this further discussion, this article proposed a working definition of microgrids for the EU legal framework.

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