International Conference on Electricity Distribution

Working Group

Final Report

Microgrids Business Models and Regulatory issues

Taxonomy of microgrids business models and regulation Grid-connected microgrid economic outlook

CIRED

WG 2019-2

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Working Group

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Microgrids Business Models and Regulatory issues

Taxonomy of microgrids business models and regulation Grid-connected microgrid economic outlook


http://cired.net/
m.delville@aim-association.org

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This report delivers the answer of a group of experts united into the CIRED Working Group 2019-2, to the following requirements and questions.

Scope, deliverables and proposed time schedule of the Group:
<u>Background:</u>

> *Microgrids, which can be operated **either** while **connected** to the surrounding power system or while **islanded**, can be a solution to improve resiliency or continuity of supply and to facilitate the development of various services to power systems. The development of microgrids depends on the **business models** of involved stakeholders. lt raises complex **regulatory** issues, including, for instance, the rights and duties of parties, the impact on costs for participating vs. non-participating customers, the economical or societal value of socializing some costs, etc.*

<u>Scope:</u>

> *The working group will caver issues related to business models and regulatory issues as a complement to CIRED WG 2018-3 (Technical requirements for the operation of microgrids in bath interconnected and islanded modes).*

The working group will investigate the following issues:

- *Microgrids value, taking into consideration:*
    - *a. Ability to optimize DSO's investments;*
    - *b. Resiliency and continuity of supply;*
    - *c. Provision of services to the power system.*
- *Microgrids business models.*
- *Cost/Benefit analysis for both customers connected to the microgrid and for the society.*

Most relevant existing demonstration projects and studies should be presented including, when available, lessons learned from these projects.
The Working Group will analyse what could speed up or hamper the development and the largescale implementation of such solutions, including which regulatory factors encourage and counteract microgrid services.

Final report expected on December 2020

Table of Contents

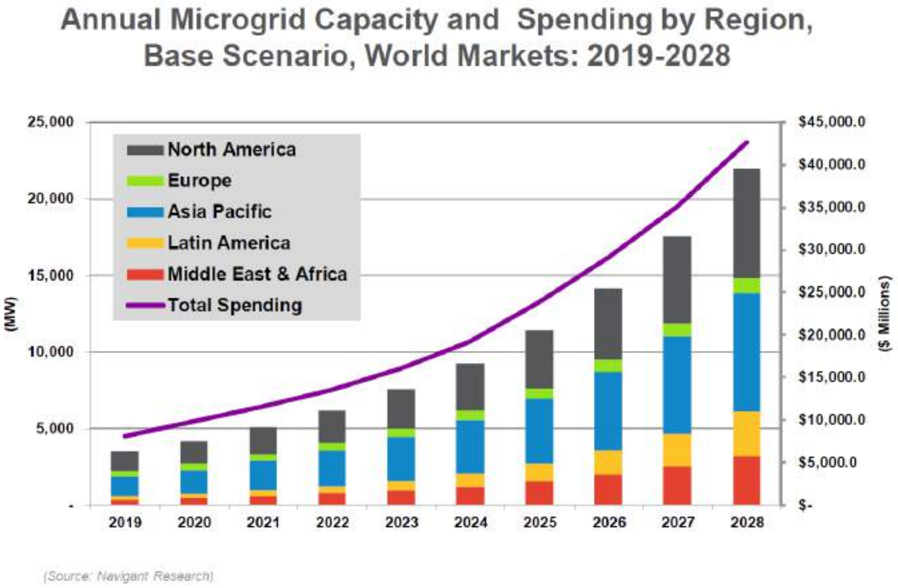
EXECUTIVE SUMMARY & PROPOSALS

Microgrid is a well-defined concept reflecting multiple realities. According to IEEE, **a microgrid is a group of interconnected loads and distributed energy resources […] which can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.**

In this definition, ownership of the microgrid is not an issue. Every possible combination exists from private to public: local customer-owned and **private microgrids; utility-owned microgrids;** local energy community with an **energy management system; peer-to-peer** platform using only the DSO network, etc.

However, this useful definition for Europe **excludes off-grid microgrids**, which are more and more common in developing countries, as shown in the graph below from Navigant research, representing the annual generation capacity installed within microgrids.

Microgrid growth is strong in Asia Pacific, Latin America and Middle-East & Africa, as microgrids do help electrify the countryland. In those countries, a significant proportion comes from very small off-grid microgrids. Microgrid development is also strong in North America, to address issues of quality of supply and resiliency of public electricity networks.



Thus, microgrid development is a worldwide reality except in Europe. Is Europe the last place where microgrids makes sense? May Europe offer favourable conditions for profitable microgrids **'business model**? Does the **local regulation** have a significant impact to hinder or foster the development of microgrids?

To address the large diversity of microgrids geographical implantations, technical design, business models, the working group choose to summarize through a **3x3 'Microgrids' Magic Matrix'** (see the scheme next page) some different functions of microgrids, addressing:

- **3 main Abilities** to improve **reliability**, **resiliency**, **efficiency**
- **3 main Benefits**: **economical**, **local & social**, **environmental**

For avoidance of any doubt, the purpose of this magic matrix is not to allage that only microgrids may render such functions, or that microgrids shall replace grid development. **The purpose of this magic matrix is to make simpler and faster the understanding of microgrid's issues and projects.**

MICROGRIDS' MAGIC MATRIX

Key Ability	Benefit: Economical	Benefit: Local & social	Benefit: Environmental
Reliability (7/24)	❑ Improve **Quality of Supply** ○ **Electrification!** ○ **Continuous supply** ○ **Power Management: voltage & frequency quality** ❑ Defer or withdraw **grid reinforcement** investments.	❑ Increase local & social **acceptance** of Grid projects	❑ Only solution when there is **no environmental right to build a line** ❑ **Endeavor DER:** DER in microgrids contributes to reducing fuel consumption & CO2 emissions
Resiliency	❑ **A microgrid is better than no grid:** mutualizing and reducing the number of emergency generators or storage ❑ **Improved resiliency against Grid contingency** ❑ **Black-start services**	❑ Powering **emergency shelters**: army, hospitals, homecare, universities…	❑ Allow to face **extreme weather conditions** with climate change (cf. fire with PG&E, Australia, mud flow in France, sticking snow…)
Efficiency	❑ **Energy savings** ○ **Phase Balancing** improvement ○ Local generation reduces losses ○ **Energy Management**: storage & demand side management reduce the Peak load ❑ **Local Energy Market participation & revenues** (Local settlement, P2P, Blockchain) ❑ May reveal the full value of **flexibility** (Smart City Services, aso). **Materialize local Non Distributed Energy Value?**	❑ **Plug and Play** in MV as in LV, to allow… ❑ **"Self care"** : local actors take care of the grid and their consumption ❑ Opportunities toward new energy governance: cf. **Local Energy Communities**	❑ **Reduce CO2 emissions** ❑ **Multi energy & cross sector coupling**

The Working Group, based on 12 examples described in appendix, came with the following conclusions:

In developing countries, off-grid microgrids seem to be a competitive solution to **bring green electricity** on areas at the edge of the grid, or in electrical deserts.

In Europe, **if their prices decrease significantly**, the **Energy Management System embedded in each micro-grid may lead to new services** as such as:

- **In the country land**, improve the **quality of supply** and the **resiliency** of the grid, especially using the capability to adjust local demand to local DER generation capacity and storage, and to allow fresh start-ups during grid outage, using the local generation;
- **In cities**, microgrids appear as a **specific form of Energy Communities**, but not every Energy Community will be a microgrid. Microgrid may foster **peer-to-peer exchanges** between participants or may allow the development of **new kinds of services** to the DSO, such as: "collective cap option" on demand level, or local ancillary services...

As an outlook, we guess that the worldwide development of DERs and EV will continue to lower the cost of the main components of microgrids, and will allow, in a middle or long term future, a profitable **development of DC microgrids**. A future CIRED Working Group will analyse the existing demonstrators and underline the value of specific services allowed by that DC systems & regulation.

1 INTRODUCTION

1.1 LOCAL VS GLOBAL, MICROGRIDS VS SILKROADS

The different companies working in the electric industry and involved in the CIRED working groups are facing main changes. In his paper of November 2019 published by the IFRI (French Institute of International Relations) “Les défis de la transformation du secteur”, the famous French economists Jacques PERCEBOIS identified three main changes: pricing efficiency with increasing feed-in tariffs, digitalization and the development of tomorrow’s network : “**should we favor mini-or even micro-grids to integrate electricity production that will be increasingly decentralized and self-consumed tomorrow, or should we, on the contrary, opt for the interconnection of large international grids like the "electric silk road" envisaged by some Chinese operators? Are the two solutions reconcilable?”**

To better understand the technical specificities of micro-grids and define the limit of their scope, Vincent DEBUSSCHERE led a first CIRED Working Group *(*WG 2018-3) from 2018 on. We would thank him for the precious material delivered by this working group.

Microgrids technology is available *as can be seen in the assessed* ***European demonstrators*** *and in more operational cases in other* ***rural areas*** *of the planet (Asia, Africa, South America, etc.) were microgrids have been extensively deployed. In Europe, microgrids have not been largely deployed since the integrated interconnected distribution grid concept that has been built over decades, currently operates securely with reasonable costs and acceptable safety levels.* ***Excluding economics, most of the technology is available*** *or at least industrially mature, though requiring improvement and generalization in standards on particular components. However,* ***the technical changes in the grid infrastructure would be significant and the benefits of such operation would have to be carefully assessed*** *before transitioning to a system where safety issues could be* ***more complex to handle****. Nevertheless, for future distribution grids where distributed grid operation principles, active prosumers and even more distributed generation increase in variability and complexity,* ***microgrids could act as a powerful tool ensuring some resilience while providing flexibility to distribution system.***

Following its track, the WG 2019-2 “Microgrids B.Models and regulatory issues” worked on to give a better highlight on the different business models and regulation. The present report answers the following questions, using the shared knowledge of 12 use cases presented in appendix 7.5.1:

- What are microgrids?
- Why are microgrid useful?
- Microgrids’ ownership and Buisness Models
- Regulation?
- Proposals & conclusion

1.2 MEMBERS

We were a team of 10 active members and contributors to the report, working in 8 different countries

2 WHAT ARE MICROGRIDS?

2.1 IS ANY GRID A MICROGRID?

The history of electrical networks development demonstrates that they result from a double movement. **A top-down movement** led transportation networks to be built to bring the hydraulic force towards factories, cities and railroads. The **bottom-up movement** led the local political forces and industries develop local grids and step by step connected them to the main grid.
However, any grid which is part or connected to a distribution network may not be considered as a microgrid. Indeed, microgrid definition has been accurately defined.

2.2 MICROGRID DEFINITIONS

Two schools of thought have advanced prominent definitions for a microgrid, namely, CIGRE's Working Group C6.22 and the US Department of Energy (DOE)'s Microgrid Exchange Group (LBNL 2019).

Table 21 - Microgrid definitions according to CIGRE's working group C6.22 and IEE or US DOE's microgrid exchange group

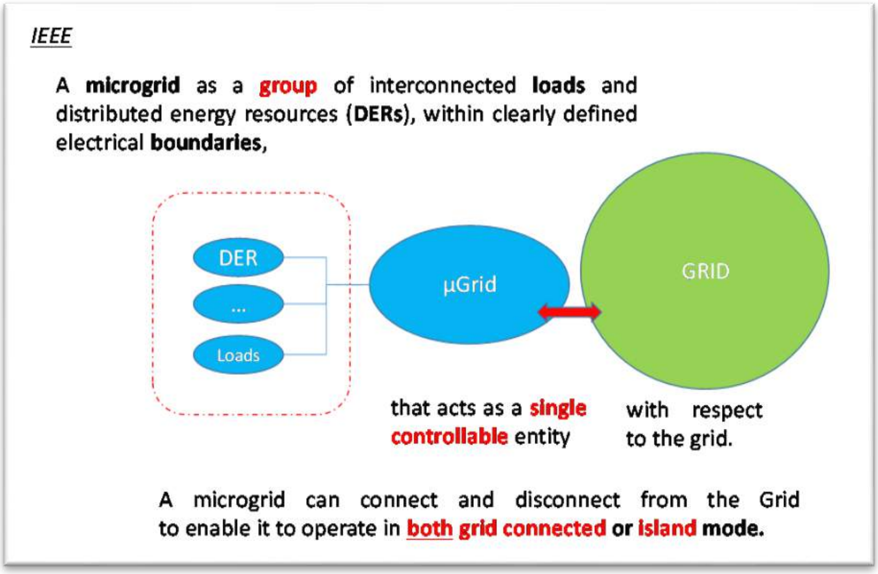
International Forum	Definition
CIGRE's Working Group C6.22	*Microgrids are electricity distribution systems containing loads and distributed energy resources, (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way, either while connected to the main power network or while islanded (CIGRE WG C6.22, 2015).*
IEEE **or** **US DOE Microgrid Exchange Group**	*A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode (Ton and Smith, 2012).*

Both definitions consider **three key requirements** for a microgrid:

1. Forming electrical clusters composed of both **DER** and customer **loads**;
2. **Internal asset control** and coordination, posing no disturbances to the grid;
3. **Ability to isolate and operate islanded** from the distribution network.

The above are the defining criteria for a microgrid system, which means **microgrids are not bound** by factors such as **size** (which is dictated by the DER's scale), **application**, employed **technologies**, or **customer type**.

For our study, we decided to use the IEEE definition:



2.3 MICROGRID'S DEFINITION DOESN'T INCLUDE ANY GEOGRAPHIC LIMITATION!

It is astonishing that the **IEEE microgrid definition implies no geographical limitation**. A regional or a country network may be controlled, connected to or disconnected from the European copper plate. However, it does not constitute a microgrid because it is not local enough *to act as a single controllable entity with respect to the grid*.

Depending on the voltage level of the grid you're considering, the size of a microgrid may differ considerably. For example, if you consider:

- the HV network, a smart city or a smart district is a microgrid;
- the LV network, any smart house with PV or electric storage is a microgrid.

First microgrids were developed as autonomous systems in **non-connected areas**, that are **non-connected islands** or far distant areas in Africa.

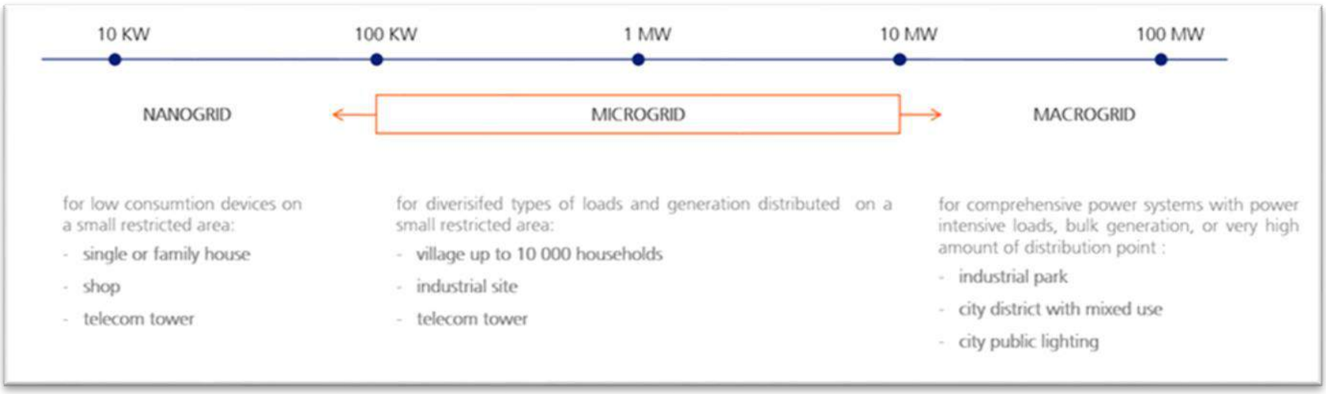
Non grid-connectable microgrids are also used in **closed biological systems**, in **satellites** or in **space** bases (cf. ww.crom.et.aau.dk)

Moreover, **any electric vehicle by itself shall be considered a microgrid**, as it:

- includes DER with its battery
- may act as *moving* single controllable entity (with respect to the grid, regarding the local legislation)
- can connect or disconnect from the grid (and enable it to operate in the case of vehicle-to-grid)

Therefore, the common agreement is to distinguish between **nano-**, **micro-** and **macrogrids**. Microgrids power range is central, between 0.1 MW and 10 MW, as per IEEE's recommendation (Chowdhury, 2009).

Table 3: Microgrid size by power range



3 WHY ARE MICROGRIDS USEFUL?

3.1 THE TRIPLE ROLE OF MICROGRIDS

In their reference contribution to the microgrid industry, GIRI VENKATARAMANAN and MARNAY (2008) have discussed the **triple role of microgrids** and the larger role they may play in the XXI[th] century. The following table, extracted from the publication "Overview of Microgrid Developments in Europe & Africa", Mendes and GUERRERO (2019):

Mature market economies	Emerging market economies	Developing market economies
"Transforming Growth" *(Venkataramanan and Marnay, 2008)*	***"Managing Growth"*** *(Venkataramanan and Marnay, 2008)*	***"Expanding Reach"*** *(Venkataramanan and Marnay, 2008)*
▪ Flexibility requirements (RES penetration, shifting electrical demand from PEVs, HVAC,…) ▪ Enhanced market operations and community empowerment ▪ Diesel offset in islands	▪ Weak grid support ▪ Maintenance and enhancements of PQR ▪ Rural electrification	▪ Rural electrification

From the right to the left, microgrids allow to:

1. **Expanding reach**: In the developing world, microgrids serve the purpose of **getting electricity to where there is no grid**. This is the most extreme realization of rural electrification projects, with wide humanitarian implications. In this context, there's usually no expectation that the grid will eventually arrive in a foreseeable future.
2. **Managing growth**: In emerging economies, facing **rapid** population **growth**, energy demand, and quality of life standards, grid extension may not be able to keep up. Thus, microgrids can **help manage grid infrastructure upgrading**. In these cases, microgrids are technically prepared for a connection with the distribution grid that will come later in time.
3. **Transforming growth**: In the developed world (mature market economies), energy problems have a substantially different nature. Almost everywhere, Power Quality and Resiliency is virtually pristine, and electrification is universal. In this environment, microgrids can help in increasing **the efficiency of resource use,** by leveraging the many advantages of local energy production, greening the energy system through **energy efficiency** and **RES adoption**, serving energy customers heterogeneously (an alternative to universal PQR service), and shifting the power balance, by contributing to customer empowerment via potential involvement in LECs and participation in energy markets.

   Of course, in such mature market economies where the grid quality is pristine, **microgrid is not the only alternative solution**: there is a **continuum of interesting solutions using the DSO grid until the microgrids' solution**, as discussed from §5.3 on, such as: §5.4 Collective Self Consumption, §5.5 Energy Communities, §5.6 Citizen Communities…. And the drawbacks of microgrids' solutions (technical complexity & cost) discussed in §0 shall remain for at least a decade**.**

3.2 MICROGRIDS: CATALYSTS OF THE ENERGY TRANSITION

Microgrids have initially emerged as a technical approach for **independently controlling and coordinating DER assets located at the edge of the grid** (LASSETER, 2002). This allows microgrid systems to connect to the distribution grid in **one single point** (point of common coupling – PCC) without posing significant power quality or load disturbances. Microgrids can also seamlessly disconnect from the main grid and operate autonomously, if circumstances so dictate, as well as reconnect, when timely. This distinctive feature of microgrids provides great value in a context where the **penetration of intermittent renewable energies** continues to rise globally and where the patterns of electric demand are undergoing major transitions as a result from the **electrification of heating, cooling, and transportation sectors**, among others (NREL, 2021; BURGESS ET AL., 2020; BOßMANN AND STAFFELL, 2015). By solving **resource control** at the distribution network level, microgrids can be **perceived** as modernization **alternative to traditional grid expansion and other transmission and distribution (T&D) level upgrades**.

From that perspective, microgrids may offer some level of **investment** deferral to Distribution System Operator parties, and thus may **shorten connexion delay**. Microgrids may also **reduce the total needed grid development costs**, as lower investments may be required if microgrids energy management systems succeed in flattening the load curve, in injection or withdrawal.

At a country level, microgrids may also offer various **flexibility to the electricity market or electric system**, from long term to short term products: capacity markets offers, balancing or flexibility offers, ancillary systems offers.

At a more local level, microgrids render local, social and economic, benefits. Microgrids may foster the development of DERs, and the local commitment of local inhabitants or users. Moreover, from an economical point of view, an efficient **Demand Side Management or Energy Management System** allows to maximise the use of locally generated energy or to store it to maximize its value when sold on the market. **Grid Forming** (cf. Clean Energy Package, articles 2, 31 and 40) components allow microgrids to help guaranteeing the voltage or the frequency level or the wave quality. Moreover, as **local users are committed** into the microgrid efficiency, microgrid may also improve the **phase balancing** through human action or with automatic artefacts.

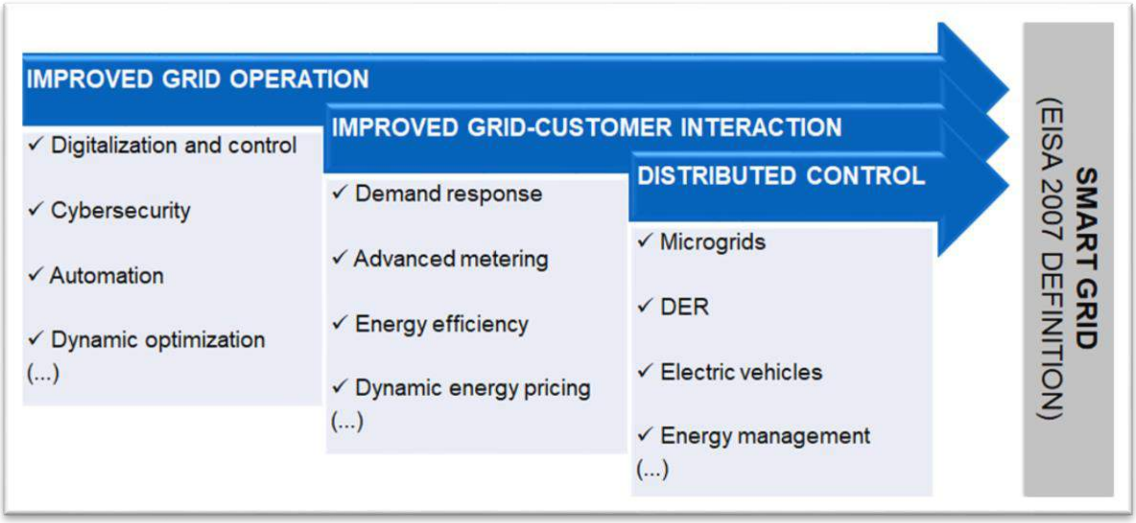


Figure – The three pillars of the smart grid, according to EISA'S vision.

Other microgrid benefits may have a **more localized nature**, and could include:

- **Energy efficiency and integration**: explain and link to savings potential
- **Emissions offset**: explain and link mostly to local carbon substitution but make mention as well to global impact emissions (CO2) as well
- **PQR improvements**: explain and link to weak grid and tailored power quality cases
- **Local empowerment and growth**: explain and link to potential revenues from integration in markets, local benefits leveraged by DER, renewed role of customers in the energy markets

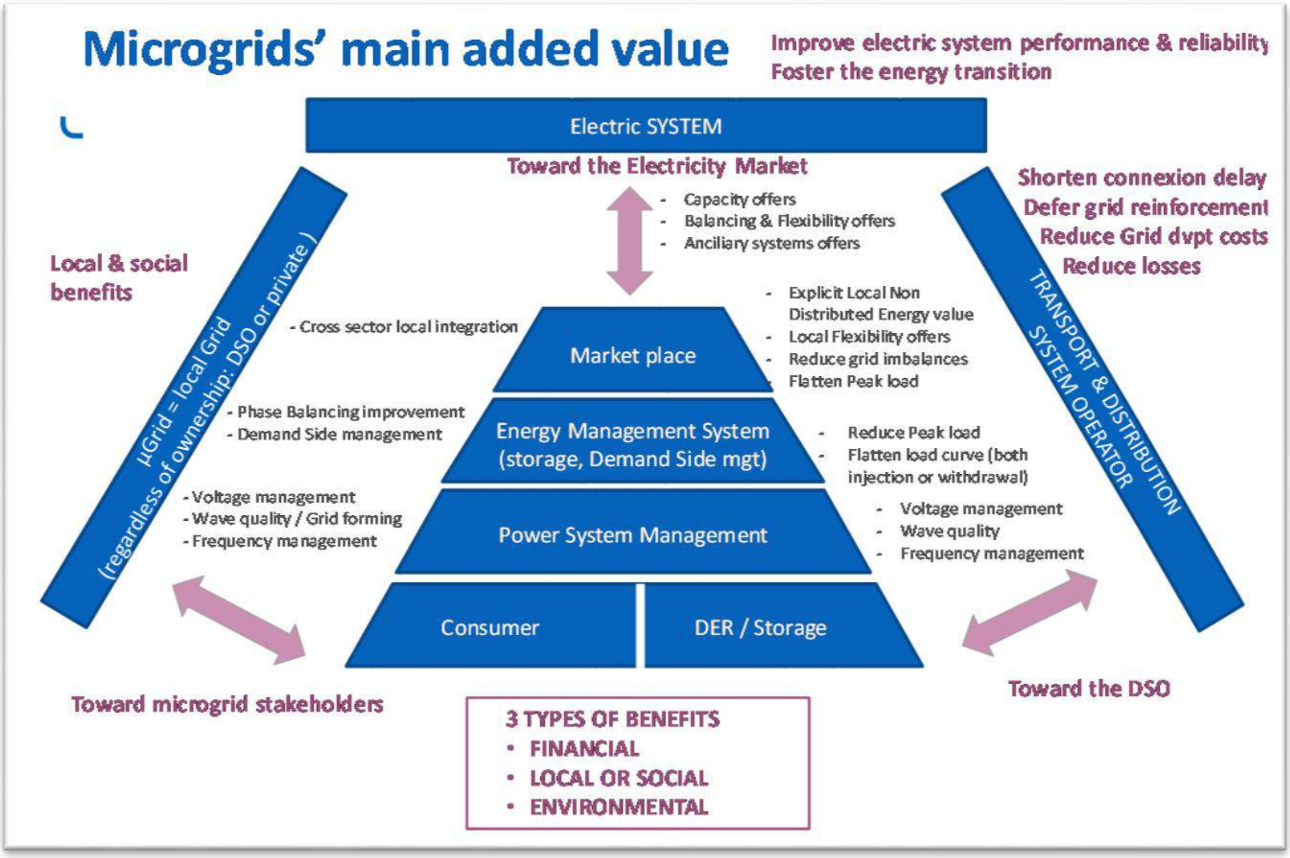
3.3 MICROGRIDS' ADDED VALUE

The EISA's holistic vision of smart grid is based on a three-legged scheme:

1. **integrate the distributed network control**
2. **improved legacy grid operations** and
3. **enhanced grid-demand interaction**

More accurately, according to MARNAY (2018), microgrids **integrate the** first pillar, **distributed network control key pillar**.

We tried to summarize in the following scheme all the microgrids' added value.



4 MICROGRIDS' OWNERSHIP & BUSINESS MODELS

4.1 DEVELOPPMENT PERSPECTIVES FOR MICROGRIDS: SWOT ANALYSIS

Considering all these interesting trumps, why are microgrids no more often used around the world? To answer that question, the WG worked onto a **SWOT analysis on microgrids.**

STRENGTHS	WEAKNESSES
▪ Easier deployment of **renewables** ▪ Local control enables **granular optimized** operation of generation and consumption and contingency anticipation ▪ Improved **resiliency** ▪ Enables **flexible** use of energy sources ▪ **Democratize** the energy playfield ▪ Enables **communities** at any location to have stable energy	▪ **Lacks the economy of scale** ▪ **Less professional management** High dependency on renewables **require costly energy storage or the customer acceptance to adjust their demand** ▪ Reduced quality assurance and operational process
OPPORTUNITIES	**THREATS**
▪ **Converge** infrastructure operations (ie. EV, smart city, buildings) ▪ Opportunity for **small and local** businesses ▪ Leverage the local **data** for various process management ▪ The **profitability criteria** of microgrids are neither simple nor simplified by competitors	▪ **Solidarity devil cycle:** wealthier communities may increase the burden on weaker ones (by being disconnected from the grid) ▪ **Price may win over quality**, resulting in degraded power infrastructure ▪ Open architecture increases the **cyber-attack risks**

This SWOT analysis demonstrate that microgrids are particularly fitted to be deployed **at the edge of networks**, as they provide electricity at an **economical cost but with more usage constraints** on the **Demand Size Management**.

At the core of the network area, electricity supplied from the grid is available at any time with a competitive cost, allowed by network and generation assets costs sharing, in dense areas.
However, **when the grid quality is not sufficient enough** (no more connexion capacity, high SAIDI), microgrid allow to benefit from both:

- the **grid core service** most of the time in *connected mode* and
- the **microgrid local management system** in *disconnected mode*, to lower the impact on consumers, and on *connected mode* to improve the local energy management.

From an economical point of view, microgrids may reveal the marginal local value of electricity

4.2 MICROGRIDS' BUSINESS MODELS

A business model "describes the rationale of how an organization creates, delivers, and captures value, in economic, social, cultural or other contexts"[1].

According to this definition, it appears that a microgrid business model will vary greatly according to the asset owner or developer of the said-microgrid as each will have specific drivers to implement a microgrid assets.

4.3 MICROGRIDS' OWNERSHIP DEPENDS ON THE FUNCTION OF THE MICROGRID

Microgrid ownership takes place across project stages and may evolve with the maturity of the project. The microgrid value chain entails five key stages (MENDES AND NIGAMTULINA, 2020; SCOTNEY et al. 2019; WESTON et al. 2018; ABELLA et al. 2015):

1) **Financing**: Who secures the financing is the "investor party" and/or the main interested party in the project. The project will be oriented towards generating financial returns for the stakeholder taking charge of this stage. **Financing microgrids is challenging, due to their capital-intensive nature**;
2) **Development or design**: Involves all the early steps in the project, from feasibility and planning analyses to engineering project execution. A key step of this stage is to model and assess **performance of the DER generation mix**. The development stage is most traditionally headed by an engineering service provider, but can also be bundled into a wider engineering, procurement, and construction (EPC) contract;
3) **Implementation**: This stage is inclusive of procurement of materials and equipment as per the procurement guidelines in the engineering project. To ensure proper operation of the microgrid in the expected long-term (20–25 years), it is important that installation follows national and **international standards** and electric codes, recommended procedures, and best practices provided by reputable organizations such as the International Electro-technical Commission (IEC) and the Institute of Electrical and Electronics Engineers (IEEE). In order to simplify the project structure, the development and the deployment are often bundled into one single EPC contract;
4) **Operation**: Starts after the project is deployed in the selected site. Microgrids entail complex engineering, reason why operation is usually managed by a technical service provider, rather than staying in the hands of the microgrid customers. In many occasions, to assure efficient operation, it is the **EPC contractor** or whoever has physically deployed the project who assumes this role;
5) **Maintenance**: Happens only periodically and is unvaryingly offered inside a bundled contract with the operation of the system (operation and maintenance – O&M – contract). A good and attentive maintenance leads to lower running costs and higher savings, thus contributing to the bankability of the project. To assure this, internationally acknowledged **best practices** such as preventive maintenance and establishment of a comprehensive O&M plan should be established.

Based on MENDES AND NIGAMTULINA (2020), **two major types of ownership models** have become dominant (see appendix 7.2 Detailed microgrids ownership business models) amidst the portfolio of contemporary microgrid projects:

1. **Customer ownership models**;
2. **Third-party ownership models**, including microgrids owned or operated by grid operators/utilities.

1. Customer ownership

Projects developed under a customer ownership model rely extensively on **manageable upfront costs** and **clear value propositions**. In the design of these microgrids, simplicity is key, and greater focus is put on mature, reliable DER technologies. **The cost recovery is largely based on avoided costs**, rather than on more sophisticated income opportunities. A common way to seek further offsets is via government support mechanisms. Traditional investing customers are big commercial clients with **substantial expenditures in energy and power**, as well as customers plagued by **unreliable electric service**. It is not rare that project design is handled in-house, but the system's deployment is unvaryingly managed by an EPC provider. Depending on the customer's capacity and area of activity, **O&M may be taken on by internal teams** or

[1] https://en.wikipedia.org/wiki/Business_model

secured via a LTSA with a service provider. **Projects in this domain are often power and heat-based**. As a result, customers retain their contracts with both electric and fuel retailers, trading-off between local generation and purchases to their best economic advantage. MENDES AND NIGAMTULINA (2020).

2. Third party ownership

Projects developed under a third party-ownership model **transfer the responsibility over an entire microgrid project's value chain to one or more third parties' shoulders**. In these cases, **the grid operator/utility is usually tasked with O&M of the portion of the distribution network servicing the microgrid.**

- **Customer Owned microgrids (CO)**: Customers willing to engage in such projects wish to **modernize** their energy operations but are usually not in a legal or financial position to invest MENDES AND NIGAMTULINA (2020),.
- **Third-party funded grid-connected microgrids (TPO)** make use of **sophisticated control engineering** for leveraging the highest possible number of revenue streams from open energy marketplaces MENDES AND NIGAMTULINA (2020),. The investment is also eased by accessing various kinds of incentives. The highly **innovative technical, regulatory, and business environment** from which these projects emerge is not without substantial risks, but its value creation potential is unparalleled. There are myriad configurations these projects can take. Two specific kinds of TPO microgrids may be noticed:
    - **Public-Private Partnership (PPP)** are financed by private funds though the control of the operation is kept by public authorities which are committed to rent a service over a long time period
    - **Utility microgrids (UO)** are **owned** or **co-owned** by **grid operators. Assets are located within their service territory**. Most are geared toward maintaining minimum PQR levels in troublesome areas of the power grid, but others accomplish broader goals. Utility microgrids are **unconventional** but play a crucial role in the wide-ranging service and technical modernization of the T&D sector.

As we just overlooked, microgrid ownership is a complex question, which may impact the contractual and financing scheme, but should not alter the profitability accessed through different business models.

Usually, Ownership and Business model are linked toward a common purpose, for example:

- Customer-Owned and Third-Party: Financial profitability
- DSO owned microgrid: Electrical system benefits
- Community owned microgrid: Access to a reliable 24/7 electricity

Therefore, in the WG 2019-2, **we believe that the ownership is less important** than the different **functions** that a microgrid allow to reach. Indeed, microgrid are digitalized enough to drive or to organize the local energy and ancillary services markets or commitments; and also to drive the interface and complementarity with the upside regional grid.

That's why, based on several cases studies, we set up **a microgrid magic matrix taking into account the couple benefit / ability.**

4.4 MICROGRID MAGIC MATRIX

In an energy sector in constant change, the WG summarized its passionate discussions to propose a **compass** to help navigate and understand the value promise of numerous microgrid projects under a context with Volatility, Uncertainty, Complexity and Ambiguity.

Based on the analysis of 12 microgrids (see Appendix 7.5.1), we proposed a 3x3 Magic Matrix, with:

- In columns, 3 main **benefits**: economical, local & social, environmental;
- In rows, 3 main **abilities**: reliability, resiliency and efficiency.

MICROGRIDS' MAGIC MATRIX

Key Ability	Benefit: Economical	Benefit: Local & social	Benefit: Environmental
Reliability (7/24)	❑ Improve **Quality of Supply** ○ **Electrification!** ○ **Continuous supply** ○ **Power Management: voltage & frequency quality** ❑ Defer or withdraw **grid reinforcement** investments.	❑ Increase local & social **acceptance** of Grid projects	❑ Only solution when there is **no environmental right to build a line** ❑ **Endeavor DER:** DER in microgrids contributes to reducing fuel consumption & CO2 emissions
Resiliency	❑ **A microgrid is better than no grid:** mutualizing and reducing the number of emergency generators or storage ❑ **Improved resiliency against Grid contingency** ❑ **Black-start** services	❑ Powering **emergency shelters:** army, hospitals, homecare, universities…	❑ Allow to face **extreme weather conditions** with climate change (cf. fire with PG&E, Australia, mud flow in France, sticking snow…)
Efficiency	❑ **Energy savings** ○ **Phase Balancing** improvement ○ Local generation reduces losses ○ **Energy Management:** storage & demand side management reduce the Peak load ❑ **Local Energy Market participation & revenues** (Local settlement, P2P, Blockchain) ❑ May reveal the full value of **flexibility** (Smart City Services, aso). **Materialize local Non Distributed Energy Value?**	❑ **Plug and Play** in MV as in LV, to allow… ❑ **"Self care"** : local actors take care of the grid and their consumption ❑ Opportunities toward new energy governance: cf. **Local Energy Communities**	❑ **Reduce CO2 emissions** ❑ **Multi energy & cross sector coupling**

We hope that this **microgrid magic matrix** will be as useful as it were for us to categorize the projects, as we did in Appendix 7.4).

Notice: the difference between Reliability and Resiliency is not so obvious. We get an excellent definition by Teresa HANSEN, Editor in chief of Powergrid international. The difference between grid reliability and grid resiliency. Although the two terms often are used interchangeably, they are not the same.

- **Grid reliability** is commonly defined as the ability of the electric power system to **deliver** electricity in the quantity and with the quality demanded by end-users.
- **Grid resiliency** is the ability for the electric power system to withstand and recover from **extreme**, **damaging conditions**, including weather and other natural disasters, as well as cyber and physical attacks. While the two are different, resiliency directly impacts reliability

5 MICROGRIDS' REGULATION AND GOVERNMENT SUPPORT

5.1 REGULATION IS KEY FOR MICROGRID DEVELOPMENT

However, if microgrids ownership is not so important for business models, **regulation** remains an interesting issue for the development of microgrids, especially in Western Europe, where the public network has a good performance and quality and where **private networks threaten to hinder the solidarity between urban and rural grid users.**

Micro-grid regulation is a wide topic which has not, so far, received a global and uniform answer. Because it is a **world-wide subjec**t, it seems impossible to define a common and unique regulation for micro-grid at this scale.

There is a strong stake for the development of a clear and shared regulation for microgrid project. Common and clear regulation is considered as key tool to ensure a well-development of micro-grid on a large scale. (MARNAY 2012) considers for example the main regulative problematics resistance from vested interest group on interconnection regulation with microgrids would deeply influence cost of deployment for micro-grid project depending on each country. (ALI et al. 2017) notice the necessity to a common regulatory perspective for micro-grid development, at least in European Union. The author argues than "after providing the funds and incentives for maximum deployment of microgrids, new challenges and barriers arise, such as the **differences in national policies and regulation of each EU member state**".

Indeed, as well explained by (WOUTERS 2015**), a common and robust regulatory framework for micro-grid is still in its infancy, unless the massive development of projects all around the world.**

We observe than even in "developed countries" **there is a lack of common and well-established regulatory framework**. (MARNAY 2012) in this overview of microgrid regulation and economics' barriers notify than in Europe, U.S and Japan, unbundling and liberalization of electricity market, should allow a better integration of independent power producers such as microgrids. But a wide aspect of micro-grid's regulation stays uncovered, and **microgrid issue are often linked to renewable integration regulation without a specific and clear treatment** (ALI et al. 2017).

5.2 EMERGING MARKET ECONOMIES: TAILOR-MADE MICROGRIDS

In other countries, it is necessary to take into account than, mainly in developing country, **microgrid project are developed in isolated area, without existing electric system and established regulation**. Microgrid project are **often tailor-made** and are **hardly comparable** in terms of regulation requirement. We observe for example, than in projects developed in island near Singapore (WOUTERS 2015), or in several countries in Andes Cordillera (LÓPEZ-GONZÁLEZ et al. 2017), than regulation was not developed and considered before micro-grid development.

5.2.1 Myanmar

With over 80% of the rural population not yet connected to the national grid, **Myanmar is the least electrified country in Asia**. The government has started promoting the use of microgrids to fast track the electrification of the remote communities in parallel to the development of national transmission and distribution grid. The goal is to achieve a universal access to electricity by 2030.

World Bank and other International Financial Investors have supported the Burmese government since 2014 with the creation of the **National Electrification Program (NEP)**. This program is including an off-grid initiative which is managed by Myanmar's Department of Rural Development.

This off-grid initiative consists in the support for private developers to build, **operate and maintain off-grid microgrids to connect local communities with 24/7 electricity where usually no or very scarce access exist with diesel gensets.** Those microgrids are usually sourcing their energy via renewables (solar PV panels, small hydro or biomass) backed with a variable generation part from diesel genset to support the economic profitability of each individual project.

The typical communities connected to those microgrids consist of few hundred of households, small businesses (e.g. workshop, carpenter, grocery store…), public services (hospital, school, street lighting…) and sometimes telecom tower operators. The average peak load served in Year 1 of the microgrid is few tens of kilowatt.

The funding for the initial investment of those microgrids is usually as followed:

- 60% by an IFI (e.g. World Bank, Asian Development Bank…)
- 20% by the private microgrid developer
- 20% by the village electricity committee (e.g. the local community)

It is worth noting that no service level agreement is signed between the microgrid operator and the local community meaning that no penalty is charged in case of blackouts. **The regulation is based on "best effort"** philosophy from the microgrid operator. Of course this lack of incentive for the residential load can be different when a power purchase agreement exist between the microgrid operator and a private customer such as a telecom tower. Those contracts usually integrate a service level agreement to match the needs of the private customer.

Despite the absence of public regulation for the quality of supply for those privately developed microgrids, a **regulation does exist in Myanmar for technical guidelines and structuring of the tariffs** that will be charged to the different profiles of those microgrids customers. The overall principle is described in the "Mini-grid Guidelines[2]" and the technical requirements are described in the "Mini-grid Technical Guidelines[3]".

Those microgrids required as well a mandatory commercial license to operate that must be obtained before the microgrid operator is able to sell electricity to its customers.

5.2.2 Indonesia

Main configuration: on-grid microgrids in very small electrical systems **(islands of 10 000 households).**

The main off-taker is usually the national incumbent utility (PLN) that acts as a "regulatory" entity setting the local tariff targets that the microgrid developers will have to comply with.

[2] https://www.drdnepmyanmar.org/sites/drdnepmyanmar.org/files/nep-document-docs/supportdoc1_minigridguidlines_v2.pdf

[3] https://www.drdnepmyanmar.org/sites/drdnepmyanmar.org/files/nep-document-docs/supportdoc2_minigridtechspecs_v2.pdf

5.3 MATURE MARKET ECONOMIES : MICROGRIDS DEVELOPMENT DEPENDS ON THE QUALITY OF SUPPLY OF THE GRID

5.3.1 Singapore: support from local authorities to study microgrids integration

Singapore has been actively investigating microgrids research activities since a decade.
The first project was the Pulau Ubin microgrid testbed that was launched in 2013. This research demonstrator was funded by the national energy regulator (EMA – Energy Market Authority) and aimed at demonstrating hybrid microgrid in fully islanded environment off the coast of mainland Singapore, on the island of Pulau Ubin and aimed at tackling the following objective[4]:

- Cleaner energy: The Micro-grid Test-bed incorporates clean and renewable energy sources such as solar PV technology.
- Reliable electricity supply: End-users enjoy a continuous and reliable supply of electricity.
- Cost-competitive electricity: Electricity is provided by the consortium at a competitive price of USD0.60 per kWh. This is lower than what end-users paid using their own diesel generators.
- Scalability: End-users can consider higher load electrical appliances such as refrigerators and air-conditioners. This will enable businesses to expand their operations and operating hours.

Academics and industrial partners launched the REIDS[5] (Renewable Energy Integration Demonstrator Singapore) in 2017 to allow up to 10 microgrids from different vendors to interoperate with each other using a 400V/6,6kV islanded grid to assess the technological challenges of interoperability. As of early 2021 the REIDS consisted of 4 active microgrids. This research project is funded by the national research fund highlighting the support of the authorities for microgrid related topics.

The latest initiative is the PRIMO research project (Platform foR Interconnected Micro-grid Operation) that was awarded in 2019 by the national energy regulator EMA to a consortium of industrial and academics partners to tackle the challenges of urban microgrids connected to a national distribution grid. It focuses on microgrid operation optimization (with respect to the electricity market) and Energy Management by developing microgrid control system and strategy for multiple interconnected micro-grids that ensures economic and reliability benefits. The underlying use-case of this project is the future digital campus and industrial park located in Punggol District. This PRIMO project aims at formulating recommendations to the national energy regulator to adapt the existing regulation especially the electricity market in order to maximize the socio-economic added value of microgrids in an urban area.

As of 2021 the Singaporean regulation does not include any specific regulatory guidelines for microgrids, whether islanded or grid-tied. The same regulation applies as for a regular generation facility or demand-side flexible load (commercial license to operate, market licenses…). It is interesting to note that the current minimum threshold to enter the open electricity market in Singapore as a contestable load is set at 2MWh[6] monthly. The PRIMO project intends to provide guidance on this value and associated market rules to foster the inclusion of urban microgrids.

5.3.2 South Korea: no regulation for microgrids

There isn't regulation for microgrids as of now but South Korea have some regulations for interconnection of distributed generators such like solar farm or wind farm including ESSs(electrical storage system).

A **few microgrid project**, using hydrogen, are in progress in mainland usually funded by Korean government or KEPCO. But there is not enough motivation to build microgrid by private sector because the **price of electricity is quite low compared to renewable energies**. KEPCO have a plan to install renewable energies and ESSs at existing 40 diesel power plants in islands until 2025. **Remote microgrids will supply more than 70% of energy at each island.** Most cost for microgrid will be **funded by Korea government** which is leading the policy so-called '**green new deal'.**

[4] https://www.ema.gov.sg/Pulau_Ubin_Micro-grid_test_Bed.aspx
[5] http://microgrid-symposiums.org/wp-content/uploads/2017/08/Remote_1_Choo_v01_20171119.pdf
[6] https://www.openelectricitymarket.sg/business/resources/apply-for-contestability

5.3.3 Israel

Main expected configuration: **Grid tied microgrids**
Whereas there is **no official microgrid regulations in Israel for now**, the topic is being studied and discussed by the regulators.
The relevant official entities are the Ministry of Energy and the Power Utility Authority. **The Ministry of Energy commissioned a study** on the broad implications, opportunities, and obstacles for microgrid adoption in Israel. The ministry also partially sponsored **two intelligent microgrid pilot projects**, and recently sponsored a feasibility study for a microgrid that can enable **independency** for large rural district. There are multiple discussions and plans at the municipal and the national levels on possible effective structures, including **Community Choice Aggregation**, **Municipal utilities**, and **Energy Communities**.

5.3.4 USA : A strong support to microgrid development

North America has been a global leader in microgrid developments through the past decade. Microgrids have rapidly rose to prominence in the region after consecutive dedicated research and development (R&D) programs emerged in the United States (US) in the late 2000s (FENG et al., 2018). Canada pioneered North American microgrids and along the years has devoted significant efforts to the promotion of microgrids (ROMANKIEWICZ et al., 2014) but developments there have been more modest.

In the United States, the drivers behind the continued interest in microgrids have been largely related to **resiliency**, customer energy **independence**, and energy **security**. The occurrence of a series of **devastating natural events**, such as Hurricane Katrina and Superstorm Sandy in the northeast, Hurricane Harvey in the southeast, and more recently Hurricane Maria, in the northeastern Caribbean, have only exacerbated these concerns and drawn attention from the general public and public policy makers. During the last decade, both government and industry **established many policies and R&D projects** that support the advancement of microgrids in the United States. These efforts take place at federal or state/local level.

Federal-level support
The role of the US federal government has largely been in support of microgrids R&D. Federal funding has supported a number of R&D programs organized runby the Department of Energy's Office of Electricity Delivery and Energy Reliability (commonly known as Office of Electricity), each sponsoring multiple microgrid activities of various designs. By doing this, the Office of Electricity **expects to develop commercial microgrid systems under 10 MW** that are "capable of reducing outage time of required loads by more than 98% at a cost comparable to non-integrated baseline solutions while **reducing emissions by more than 20%** and improving system energy efficiencies by more than 20% by 2020" (US DOE, 2019a). Over the years, the Office of Electricity funded not only demonstration projects, but also the R&D of microgrid modeling, design, and optimization tools (DER-CAM, GridLAB-D, HOMER, etc.) and of relevant hardware such as microgrid controllers and/or static switches (FENG et al, 2018). Invariably, national laboratories such as the Lawrence Berkeley National Laboratory (LBL), Sandia National Laboratories (SNL), the Pacific Northwest National Laboratory (PNL), and the National Renewable Energy Laboratory (NREL) have been extensively involved in these activities.

The first major microgrid initiative led by the US DOE was the **Renewable and Distributed Systems Integration (RDSI) program**, which **started in 2008** and distributed **$55 million** of US DOE funds over five years. The key focus of these projects was 1) demonstrating peak demand reduction (a 15% minimum was the RDSI requirement), and 2) developing capabilities for interchangeable operation in grid parallel and islanded modes (Ton, 2013). RDSI grants gave rise to an initial set of nine microgrid demonstrators across eight states, which include notable projects such as the Santa Rita Jail microgrid in the Bay Area, and the Illinois Institute of Technology's Perfect Power microgrid in Chicago. RDSI received extensions in later years, supporting multiple other projects (FENG et al., 2018). Detailed information about RDSI grants is available at US DOE (2019b).

The American Recovery and Reinvestment Act of 2009 (ARRA) provided the US DOE with $620 million for funding new demonstration projects under the Smart Grid Demonstration Program – SGDP (US DOE, 2019a). Although this instrument has not been as successful in funding de facto microgrid projects (FENG et al., 2018) it has catalysed many microgrid-supporting activities, such as the deployment

of advanced metering infrastructure (AMI) and the modernization of transmission and distribution assets (TON, 2013). The Office of Electricity also offers a variety of technical assistance services to states through ARRA funding (TON, 2013). These may include the development and implementation of energy plans and programs, the support with financing energy initiatives, or the help with accessing and using energy data.
The Smart Power Infrastructure Demonstration for Energy, Reliability, and Security (**SPIDERS**) Joint Capability Technology Demonstration (**JCTD**) program started in 2011 co-funded by the US Department of Defense (DOD), US DOE, and US Department of Homeland Security, with the broader goal of developing highly reliable, cyber-secure, self-reliant microgrids for mission-critical military applications. The program consisted in the design and implementation of **three successive microgrid systems** of increasing levels of complexity (which dictated the project phases). The three sites were located at the Navy and Air Force Joint **Base Pearl Harbor-Hickam in Hawaii** (Phase I), **Fort Carson in Colorado** (Phase II), and **Camp Smith**, also in **Hawaii** (Phase III). The SPIDERS JCTD project aimed at standardizing design, deployment, and operational aspects of military microgrids in order to provide principles and guidelines for future applications (TON, 2013), which eventually did take place (FENG et al., 2018). JOHNSON (2015) provides further details on the SPIDERS JCTD project.

Other US DOD programs that have funded microgrid projects include the **Strategic Environmental Research and Development Program** (SERDP – technology development-oriented) and the Environmental Security Technology Certification Program (ESTCP – demonstration/validation-oriented). These programs promote **partnerships between the military, academia, industry, and other Federal agencies** to enhance and sustain DOD's mission capabilities, while improving its environmental and economic performances. While no microgrid projects remain active under SERDP grants, a large number of demonstrations that have received ESTCP funding are still ongoing (US DOD, 2019). A significant amount of these microgrid projects (Fort Sill, Fort. Bliss, Maxwell Air Force base…) involve the participation of SNL, who developed its own Energy Surety Microgrid (ESM) design approach, which is specifically geared towards energy security and reliability for critical mission assurance (SNL was also a key participant in the SPIDERS JCTD project).
In addition to the above, microgrid investments are eligible for **federal loan guarantees**, through the US DOE's Innovative Energy Loan Guarantee Program, which collectively resulted in more than $50 billion in investments across the country (US DOE, 2019c). **Tax incentives** are also available to residential customers or businesses wishing to deploy microgrids through the **Residential Renewable Energy Tax Credit** (US DOE, 2019d) and the Business Energy Investment Tax Credit – ITC (US DOE, 2019e), respectively. The incentives do not apply to microgrid systems, but rather to specific DER technologies, such as solar PV, geothermal heat pumps, fuel cells, and microturbines. The rebates offered by these tax credits can go to up to 30% of the applicable capital costs.
The end of this chapter will be dedicated to Europe.

5.3.5 Russia

According to the specificity of Russia, it can be said that the development potential for microgrids is very high, particularly for remote regions of Russia, for example in Siberia and the Far East, but the level of their use will depend on the model for energy sector development. Now, there are two emerging models:

- innovative model – adopted under the "General Scheme of the Location of Energy Facilities in Russia" and the "**Russian Energy Strategy until 2030**" (approved by the federal government).
- structural-innovative model – proposed by the Agency for Energy Forecasting project "**Development of a Concept of Energy and Electric Heat Infrastructure of Russia on the Basis of Cogeneration and Distributed Generation".**

Since the second model proposes to significantly increase the share of distributed and local power generating capacity, the implementation of this model will substantially increase the potential for microgrid development in Russia.

However, the implementation of both models faces significant barriers at the moment. The basic barriers are as follows: regulatory, technical and social economic barriers.

This kind of system could contribute to the restructuring of energy in Russia - the transition from a centralized system that uses large sources of electricity production to the use of a variety of energy sources that are most appropriate to these natural conditions and the characteristics of individual consumers.

5.3.6 Europe: low new regulation on microgrids

In Europe, the European Commission has tried to define a common definition. They consider micro-grid (for example inside "microgrids" or "more microgrids" project) such as systems "which feature low voltage distribution systems with distributed energy sources, such as microturbines, fuel cells, photovoltaic systems, etc., storage systems such as flywheels, supercapacitors and batteries, and controllable loads, which have possibilities of being controlled for the network operation. The microgrids are connected to the distribution network but can also [operate] in island mode, in the event of a fault in the main network " (Hatziargyriou, 2009)

But, despite the fact than **more than 80 projects have been funded by European-Union**, there is no specific regulation and policy concerning the deployment of microgrid in Europe. (ALI et al. 2017). Directives have been implemented which underlines interest of micro-grid into the European Union as 2004/08/EC on the **promotion of cogeneration** based on a useful heat demand in the internal energy market (whereas #20) and amending Directive 2004/8/CE on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC. **However, no explicit common rules for microgrids are yet established.**

Obviously in Europe, the development of microgrids will **question the historical regulation:** how may be rewarded a community of prosumers proposes to actively control its network consumption and injection?

- Would they benefit:
    - from a **scale effect on the grid tariff**?
    - from **additional** revenue on local flexibility markets? Should those revenues cover the cost of implementing an EMS to operate Demand Side Management.
- Would they ask for **additional subsidies**, other than RES subsidies, for example tax or tarif exemption? Will microgrid **foster network tarif structure change** toward a more important part for power fee and a reduced par for energy fee?
- Will the possible future development of microgrids open a new era **toward nodal pricing** on network or energy markets, as forecast in the MIT's 2016 paper *Utility of the Future* and experienced in Odissey Hackathon 2020*?*
- How will microgrids organize **internal solidarity** between their members and be willing to contribute to existing national **solidarity mecanisms**?
- Lastly, what kind of new services could microgrids offer to help the integration of more and more DERs: **grid forming services**, **blackstart services**… ?

5.4 MICROGRIDS AND EXTENDED COLLECTIVE SELF-CONSUMPTION

The European Clean Energy Package settled in the Energy Market Directive II, the principle of Collective Self-Consumption, whithin the same building, and also the principle of Extended Collective Self-Consumption, using the grid within a geographically limited area.

Extended Collective Self-Consumption appears to be a promising mean to develop **"virtual micro-grids",** with respect of the two first items of IEE definitions of a microgrid: A microgrid is :

- a group of <u>interconnected loads and distributed energy resources</u> within clearly defined electrical boundaries
- that acts as a <u>single controllable entity</u> with respect to the grid.
- A microgrid can connect and disconnect from the grid to enable it to operate in both <u>grid-connected or island-mode</u> (Ton and Smith, 2012).

Firstly, Extended Collective Self-Consumption is a group of loads and distributed energy resources connected to the grid within clearly defined electrical boundaries. However, on a same distribution loop, some loads or DERs may not be part of the Extended Collective Self-Consumption.

Secondly, this group may act as a single controllable entity with respect to the grid, if a demand side management system is implemented, which is the current trend. However, it doesn't mean that the DSO may have a direct control on this entity.
Group of loads and DERs which fulfil those two conditions may be named as **"virtual micro-grids"**.
Thirdly, if this group may disconnect from the grid, it is really a microgrid. Two possibilities appear:

- Either each load has an electrical storage, which allow to operate in a grid disconnected mode;
- Or every loads and DERs are part of a dedicated network, owned and operated either by a private entity or a DSO, and for which the DSO allows DSO disconnected mode (see Corrèze Resilient Grid example).

The **Renewable Energy Community** allows private networks and microgrids, if allowed by the member state.

5.5 MICROGRIDS AND RENEWABLE ENERGY COMMUNITIES

The Clean Energy Package introduced, in the Renewable Energy Directive II, the principle of Renewable Energy Community:
At the same time, energy communities offering flexibility and consumption management services could generate some difficulties for consumers, especially for vulnerable ones. As described in chapter 4 on energy sharing and supply, if consumption management or flexibility projects require investment, especially long-term investment, consumers could be tied to the energy community and could be preserved for instance from leaving the energy community, or from choosing freely a flexibility or consumption management service provider outside the energy community. For vulnerable consumers, the situation could be more complex. ***Vulnerable consumers who usually do not have important flexibility potential, could be forced, by entering an energy community proposing flexibility or consumption management services, to reduce their basic consumption, which could lead toa dangerous situation****. At the same time, shared assets used by the energy community as a whole could provide vulnerable consumers access to the benefits the new flexibility markets offer. However, these shared assets could also imply more important costs for vulnerable consumers as part of the energy community.*

5.6 MICROGRIDS AND CITIZEN COMMUNITIES

In the other hand, Citzen Energy Communities defined in the Market Energy Directive II, are not bound to be local and doesn't offer any relevant framework for micro-grids.
However, it may define a relevant framework for virtual microgrids, if the Citizen Community is geographically restricted. Indeed, the Directive doesn't define any geographical limit for Citizen Energy Communities which may be European wide…
This EC legislation and subsequent emergence of renewable/citizen energy communities mark a cornerstone in EU policy that may drive further expansion of local energy systems and trigger new microgrid markets.

Thus, the European regulation entitle through the Renewable Energy Directive II the development of:
- **micro-grids** (private or DSO owned & operated) through **Renewable Energy Communities**
- **virtual micro-grids** (DSO owned& operated), through **Extended Collective Self-Consumption**

5.7 MICROGRIDS AND REGULATORY SANDBOXES

Regulatory sandboxes enable a direct testing environment for innovative products, services or business models that could not be carried out due to restrictions in accordance with current regulations.
In the energy sector, the use of regulatory sandboxes is quite new. In the Netherlands, first sandboxes entered in force in 2015. Whereas in Great Britain, OFGEM launched the regulatory sandbox initiative in December 2016. In both country cases, these first experiences with regulatory sandboxes were overall considered positive. The initiatives quickly expanded and evolved according to the gathered learnings.
Soon, more regulatory sandboxes is appearing in many other EU countries such as France (since 2020), Austria, Germany and Spain (IREMEL since 2020).

The following describes a clear example of regulatory sandbox, defined to implement the flexibility market in Spain. The **IREMEL** project**,** Integration of Energy Resources through Local Electricity Markets in Spanish, is an initiative driven by the Electricity Market Operator (OMIE, in Spanish) in partnership with the Institute for the Diversification and Saving of Energy (IDAE, in Spanish).
The main goal is to get to know the requirements on **flexibility**, the **management capacities of the distributed energy resources** (active customers, storage facilities, production facilities in the buildings, handling electric car charging...) in order to achieve free participation on the markets and to facilitate **efficient incorporation** of these sorts of production facilities and renewable usage in the distribution networks.
In addition, the option of isolated systems or areas is considered, in which global markets do not apply, and **local services** can be spread to the entire extension of the isolated system.
Although the model establishes a **minimum market share of 0.1 MWh** and an hourly trading base, the possibility of going to lower amounts of energy is opened, due to the local nature and to periods of 15 minutes (the latter for isolated systems).

In Europe, **Regulatory SandBoxes** fitted to the local regulation seems **to the most appropriate way to foster microgrid development**, to respond to local constraints (voltage, consumption, quality of supply, resiliency..).

6 CONCLUSION

Through along this report, we demonstrated the **promising technical and functional capabilities** of microgrids. However, the **profitability** of microgrid projects is **seldom achieved** without public contribution. Regarding the **regulation**, a common and robust regulatory framework for micro-grid is still in its infancy, unless the massive development of projects all around the world. Microgrid issue are often linked to renewable integration regulation without a specific and clear treatment. Despite the fact than **more than 80 projects have been funded by European-Union**, there is no specific regulation and policy concerning the deployment of microgrid in Europe

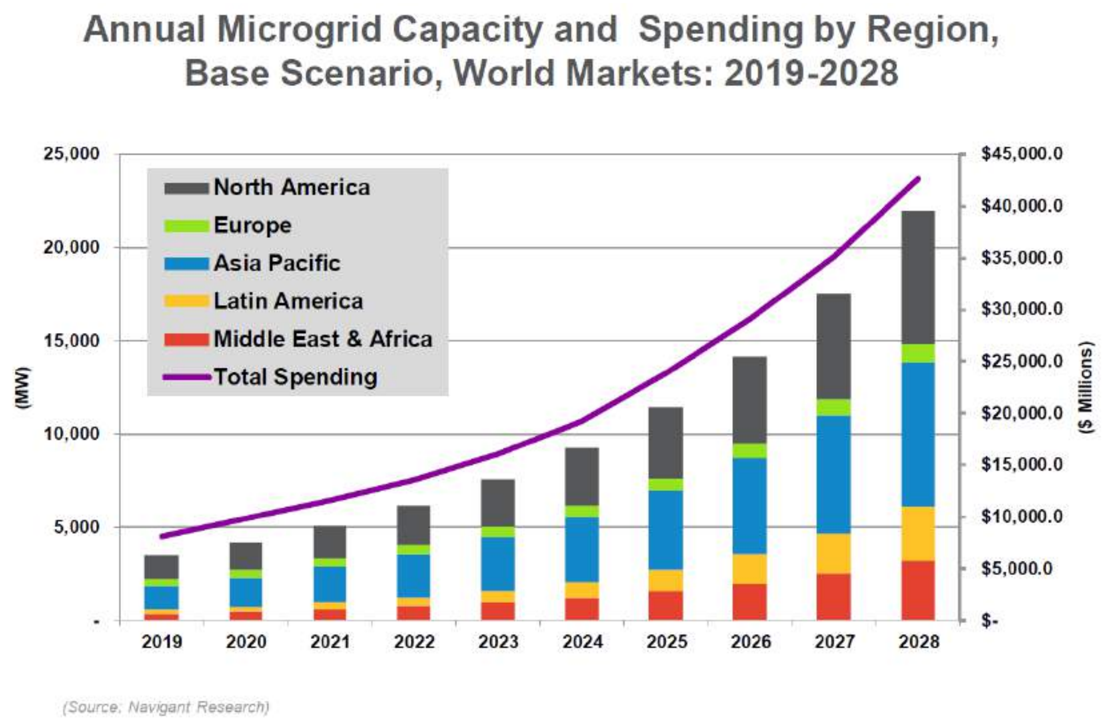
6.1 MICROGRIDS: EMBRYO OF DSO IN DEVELOPING COUNTRIES?

In developing countries, Island Microgrids will contribute to foster the energy transition, allowing to successfully replace fuel generators and to develop network at the edge of the grid. The lower is the continuity of supply expectations and the more flexible the electric uses are, the more competitive microgrids solution will be.

From now on and especially around 2025, once the PV and storage prices will have decreased sufficiently, microgrids will probably be the XXIth standard to develop electricity networks at the edge of the grid. No specific regulation shall be expected here, once the pricing of grid connection and use is duly stated.

6.2 CURRENT LOW INTEREST IN EUROPE FOR MICROGRIDS WILL REMAIN

Though microgrids are developing worldwide, Europe takes an insignificant part to microgrids' development (cf.§ 7.4.4). **Why microgrids are not taking off in Europe ?** In this section, we will try to answer this interesting question.



According to the point of view of the experts of the working group, the expectation to see fully functional microgrids "popping up" is **not realistic** in Europe or in every country where the network density and reliability are equivalent or better than the European grid ones.

Indeed, microgrids' projects still are **expensive**, require **long technical analysis**, strategic planning and decision cycles, and in many cases does not yet justify a fully functional deployment.

6.2.1 Financial: microgrids are expensive

The electricity supplied by microgrids is still too expensive compared to utility, and the appendices detail the need of public support for microgrids project. For instance, in South Kora, **microgrid electricity tariff is 3x to 4x times more expensive** than the price of electricity delivered from the grid, usually between 9 US cents/kWh and 15 US cents/kWh. This difference may decrease in countries where the solar irradiation or the wind potential are particularly high. Thus, South Korea develop microgrids on non-interconnected islands.

6.2.2 Technical: microgrids are not plug & play LEGO™

As detailed in appendices, each microgrid project is a specific, complex and dedicated project. **Microgrids are not plug & play LEGO™**, which means that microgrids are quite complex to design while the degree of standardization remain low.

6.2.3 Connected grid wins all: high quality performance of the grid limits

When a connexion to a gird with a good reliability is possible, as this is the case in Europe (SAIDI reaches 60 min/year) or South Korea (SAID reaches about 13 min/year**)**, **microgrids are seldom the best technical and economical solution.**
Thus customers connected to the main distribution grid have no need to install any microgrid. In other terms, **there is very low added value in Europe for microgrids' development.** However, microgrids might be useful in very specific circumstances, such as isolated or pseudo-isolated areas far away from the main grid.

6.2.4 Regulation: high standard to maintain high quality

Moreover, integrating a microgrid within the European grid is more complex that to build an isolated microgrid on a island. This may reduce a little more the economic interest of microgrids, compared to those in a non-connected area.

6.2.5 Perspectives

To conclude, though microgrids are not developing strongly in Europe, microgrids components are gaining popularity "under the radar" by sort of natural evolution. Year after year, there are more DER deployments, improved energy management systems, small regulations changes, etc. All those small changes will eventually transform over time and create the technical and economic conditions and the minimal regulation framework in which fully functional and cost-efficient microgrids could one day be integrated.

6.3 LONG TERM PERSPECTIVE FOR MICROGRIDS IN EUROPE: TOWARD A SYMBIOSIS BETWEEN DSO & MICROGRIDS?

In more developed countries, microgrids appear as an **historical backlash**. In the XXth century, distribution networks connected to the grid to benefit from the availability and mitigation of centralized generators. As underlined in this report, microgrids are not yet profitable without subvention. The profitability threshold may be crossed within a few decades, as micogrid management system may help:

- Answer grid expectations;
- Increase Customers' continuity of supply;
- Value excess storage in electric vehicle;
- Make easier the development of cross-sector integration;
- Coordinate the development of AC/DC hybrid networks

In a few decades, in the XXIth century, **distribution networks will benefit from the regulation capacity of microgrids to limit DER high-level injection congestions**, or to stabilize the electric system with their **grid-forming** capacities.
Moreover, with their **Demand Side Management** (DMS) or Energy Management Systems (EMS) abilities, microgrids will **offer flexilibity services to the grid.**
Microgrid may offer service to DSO, especially **flexibility** or **grid-forming** service. They may also **improve legacy grid operations,** as in Philadelphia or probably soon in the Neederlands.

The increasing number DER and **electric vehicles** will constitute a local and distributed asset with **generation and storage capacity.**

Shelter microgrids or **fresh start-up microgrids will allow to unlock hidden value. In case of outages**, most of the customers should continue to use electricity most of the time, at least, when DER are generating. Therefore, microgrids may be considered as an insurance vehicle and financed by an **insurance premium**. **Standardization** will soon be an issue, as for their development, every microgrid shall be **plug and play**.

The flexibility of microgrid Energy Management System could also be used to help control or optimize the **cross-sector integration.** Indeed, microgrid controls are designed to operate systems which are not necessarily 100% electrical.

To conclude, the working group would open the discussion to the future role of microgrid in DC grid development, which is a topic which will be dealt by an other CIRED working group.

7 APPENDICES

7.1 ACCRONYMS

AC	Alternative Current
CHP	Combined Heat and Power
DC	Digital (continuous) Current
DER	Distributed Energy Ressources
DSM	Demand Side Management
EC	European Commission
EMS	Energy Management System
EPC	Engineering, Procurement, and Construction
HVAC	Heating Ventilation And Air Conditioning
LTSA	Long Term Service Agreement
MaaS	Microgrid-as-a-Service
O&M	Operation & Maintenance
PCC	Point of Common Coupling
PEV	
PPP	Public-Private Partnerships
PQR	Power Quality and Resiliency
RES	Renewable Energy Sources
TPO	Third Party Owned (microgrid)
UO	User Owned (microgrid)

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7.3 MICROGRID OWNERSHIP FORMS

7.3.1 Customer ownership

Customers with purchasing power can decide to finance a microgrid themselves. This type of customers are most frequently large commercial and energy-consuming **clients with advantageous access to financing** (Scotney et al. 2019) and significant public exposure. By investing in microgrids, such clients can reach energy and power demand charging savings, as well as hedge against electricity and/or fuel price volatility, while significantly reducing their carbon footprint. Another subset of customers opting for this approach are those undertaking critical activities but experiencing **unreliable electric service**. The investment makes sense for those clients if costs incurred from the lack of reliability are properly internalized in the project's cash flows (Mendes and Nigmatulina, 2020). Generally, these projects involve clear and straightforward value propositions, resorting to mature, dependable technologies to ensure recovery of costs. The self-financing commitment implicates that the customer is more closely involved in the different stages of the project.

Most commonly, the engineering design and development are performed **in-house**, but, depending on the firm's expertise, contracts may be established with **engineering service providers**. EPC contractors are invariably hired for taking on the implementation stage and may or not establish LTSA agreements to operate and maintain the system. This can also be established with a specialized O&M provider or in certain cases be assured by the customer/owner themselves (Mendes and Nigmatulina, 2020).
Most customer investments in grid-connected microgrids have taken place in large building complexes such as universities and hospitals – **campus microgrids**. While no microgrid is cheap, upfront costs are typically facilitated by these not being greenfield projects, but rather **upgrades to existing legacy systems** (back-up and CHP gensets, existing distribution infrastructure, etc.). Furthermore, corporations in charge of managing such mega facilities employ own maintenance personnel, usually trained to handle complex O&M tasks.

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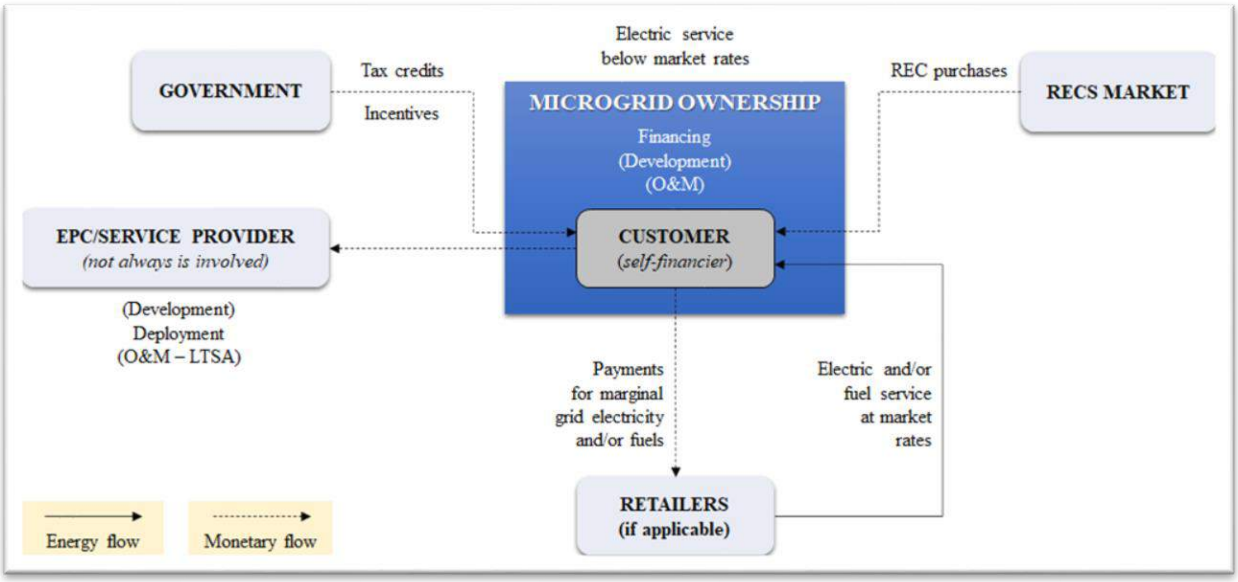


Figure - Possible structure for customer-funded microgrid business models (Adapted from MENDES and NIGMATULINA, 2020)

Self-financing is filled with advantages for those who can afford the volume of capital at play. These include a closer, more personalized approach to the project and a potentially better financial deal for the whole investment. However, it also demands greater **operational capacity from customers**, particularly its involvement across the entire project value chain, thus involving more risks.

As means to alleviate costs even further, customer-owners can apply for national or local **government incentives**, generally available for renewable energy technologies and other DER. China and the USA, for example, have implemented programs that offset upfront costs at different levels. Another popular mechanism are **indirect subsidies via credits** in the customer's **taxation**. Customers owning renewable DER can also access the market for RECs, selling them to create yet another revenue stream.

Many of the grid-connected microgrids online today (most notably in the USA) relied on this type of models. It is generally perceived as a traditional approach to microgrid development, but also a mature, lower-risk, and unswerving one, delivering moderate but solid value streams.

7.3.2 Third party ownership

The most modern and fastest growing alternative for developing grid-connected microgrid projects is through **third-party funding mechanisms** (Mendes and Nigmatulina, 2020). As DER costs go down and strict regulations become more relaxed, the financial prospects of these projects improve. More, with the progressive opening of the energy markets to **smaller-scale generation resources**, the range of potential income opportunities available to grid-connected microgrids is widening. To capitalize on those opportunities, a balance of financial robustness with dedicated expertise, robust engineering, and sophisticated operational strategies is required. Besides, this implies the **deployment of last-generation ICT setups** and power electronics, including advanced metering and interface infrastructures, as well as seamless integration with the distribution grid and varied energy marketplaces.

Arguably, only private **industry** and **grid operators/utilities** are positioned to comply with such demanding service requirements. If compared to the typical customer-funded microgrid, upfront costs and risks associated with these projects are higher. However, given the abundance of potential benefits and subsidies (either locally or nationally, such as tax credits, grants, etc.) that can be captured, these have **greater potential for value creation**, catching the eye of third-party industry and investors on the lookout for capital-intensive ventures with profitable returns. Grid operators/utilities, on the other hand, may look at microgrids as an opportunity to improve **quality of service** in their territory, **deferring expensive network upgrades and reducing customer compensation costs** (Mendes and Nigmatulina, 2020)**.**

The lifeblood of third-party-funded microgrids is removing project ownership risks from the customer's shoulders as means to drive adoption. A third party will take on the entirety or a fraction of the project's CAPEX in exchange for the agreement by the customer to some sort of long-term energy purchase commitment or cost recovery mechanism. Accordingly, business models linked to this type of ownership have been termed in the industry as "**energy-as-a-service (EaaS)**" or, more fittingly, as "**microgrid-as-a-service (MaaS).**" Lastly, while for these projects to take shape**, third parties must see in microgrids profitable investments, customers may have other value streams in mind**. Reasons to engage in such a deal could be the willingness to **modernize** a facility's energy portfolio and to hand over its management (and liability) to expert industry, as well as **strategic branding and/or corporate sustainability goals** (Mendes and Nigmatulina, 2020). Additionally, because investors/developers rely on the good operation of the microgrid for leveraging committed capital, there is a sense of greater transparency to this type of arrangement. Third party-owned microgrid projects can range from very simple one-entity undertakings to relatively complex multi-party arrangements, each with different implications for customers. The latter are far more complex, entailing a **wide range of structuring possibilities**. Here we discuss those more likely to be found in the industry. It also addresses two possible variants of grid operator/utility-oriented microgrids, which, due to their unique characteristics, stand on a class of their own.

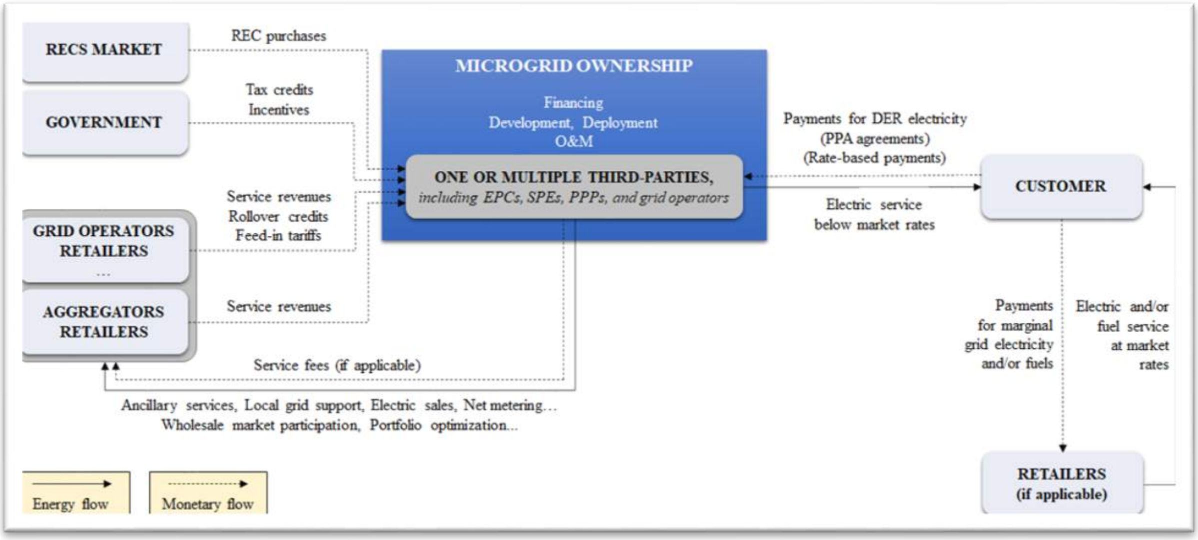


Figure 1 – Wide range of possible generalized structures for third-funded microgrid business models (Adapted from MENDES and NIGMATULINA, 2020).

7.3.2.1 Single Party-ownership

A straightforward option a customer has is **to trust the entire project value chain**, including O&M services, **to a single private entity**. A handful of third-party companies offer to develop microgrids under this model. The ability to provide such a service is limited to a privileged few, typically large multinational industry leaders, touching different areas of the business. For those who can afford it, single party-led projects generally offer substantial returns, given that all potential revenue streams within the microgrid value chain are captured. **Contrarily to the majority of customer-funded microgrid projects designed to maximize savings, this type of projects is geared toward maximizing income** (Mendes and Nigmatulina, 2020). For this reason, many projects under a single third-party model transfer ownership to an independent power producer entity (IPP), who is then eligible to take part in wholesale and other energy marketplaces. From the customer's perspective, the advantage of the single-party model lies in the **simplicity of the execution**. However, in practical terms, this model is difficult to implement, because the single-vendor option **implies a greenfield approach**, whereas most microgrid projects being launched today are retrofits.

2Various sophisticated cost-recovery mechanisms could be used to avoid third-party exposure in single-party microgrid deals, which depend on the business model adopted in the project. A common approach is to use power purchase agreements (PPA) between that party (either industry or IPP entity) and the customer.

7.3.2.2 Multiple Third Party ownership

Sometimes, customers may wish to break the delivery of different value chain activities through multiple entities (Mendes and Nigmatulina, 2020). Here, the possibilities are many and resultantly the risks are higher than in the previous case. Typically, an EPC partner will oversee engineering and deployment of the project. That entity may at times be the one bringing in the capital, but a more common approach is to have a **dedicated fund p**laying that role; **project ownership is trusted to a special purpose entity (SPE),** a third-party vehicle set up by the customer and the fund to handle financial liability and **to facilitate future ownership transmission operations**. In that situation, the SPE will be the legal entity directly contracting with the EPC provider. It will also secure the O&M of the microgrid via a traditional long-term service agreement (LTSA) with industry.
The project's returns are typically secured via customized PPA-type agreements, established between the SPE and the customer.

7.3.2.2.1 3Public-private partnerships' special case

A variant of a multiple third-party platform that **has proved (CANTOR et. Al, 2019) to successfully leverage grid-connected microgrid projects is public-private partnerships (PPPs)**. While public entities struggle to access infrastructure finance and energy investment subsidies, public facilities are both among the most massive, with very high energy costs, and the most critical to society. Private industry not only possesses the technical expertise necessary to modernize these facilities but also can leverage mentioned finance and incentives, particularly at a **tax level**. In this context, creative financial agreements may take shape under the form of PPPs for development of public-purpose microgrids that establish **win-win-win** scenarios (benefiting the **customer**, the **third parties** involved, and the **community** at large) (MENDES and NIGMATULINA, 2020). For example, high value-added microgrids can be delivered in county facilities such as fire stations or police headquarters, which cover energy demand with **clean technologies** and provide community **shelter** in case of municipal emergencies. Industry partners and infrastructure funds in various ownership configurations can finance, design, deploy, and operate these systems, as well as capitalize on any revenue-rich grid services the microgrid may offer when not serving critical uses.

The public customers will pay long-term locked-in rates for covering a share of their energy demand from the microgrid, as part of **MaaS PPA agreements**. Given the large volumes of capital invested in these projects, the PPAs may include special cost recovery mechanisms to cover part of the technical revamping. The establishment of PPPs for developing public-purpose microgrids is a low-hanging fruit on which public customers can capitalize, having been on the rise in recent years.

7.3.2.3 Grid Operator/Utility Ownership and Co-ownership

A distinct model from any of the above is that of microgrids developed by grid operators/public electric utilities **within their service territory**, **as a modernization alternative to traditional grid expansion** and other transmission and distribution (T&D)-level upgrades. Interest in this type of project has emerged largely under the auspices of US utilities, hence the term "utility microgrid." Utility microgrids constitute a ground for grid operators to **experiment new service models and develop crucial R&D in an industry that is rapidly moving toward distributed energy.** Unlike single-client microgrids serving a building or a campus, utility microgrids serve a broad range of customers, which means that the PCC is located front-of-the-meter, i.e., upstream in the network (usually at an electric substation level). As a result, **these microgrids include considerable distribution infrastructure in their asset portfolio.**

Utility microgrid ownership models fall under two main categories:

- *100% utility ownership* and
- *asset-based co-ownership*, in case split between the utility and private third party.

7.3.2.3.1 Utility ownership special case

Historically, utility microgrids have been serving the purpose of guaranteeing appropriate PQR delivery in problematic, **remote pockets of the distribution grid**. This service is **delivered locally but controlled remotely**, in balance with the conventional delivery of electricity (CEC, 2019). In those cases, not only the grid assets but also the DER are owned and managed by the utility (Mendes and Nigmatulina, 2020). Such situations are rare, since they deviate from the mandate of the utility to exclusively manage monopolistic (transmission and) distribution activities, **requiring special regulatory approval**. Public utility commissions have allowed this type of model in cases the microgrid proves to be crucial for supporting the reliable electricity delivery to otherwise marginalized customers (CEC 2019).

7.3.2.3.2 4Asset-based co-ownership case

Grid operators/utilities have more recently engaged in microgrid developments within **urban** and customer-dense areas. In such environments, **PQR is usually satisfactory**, and factors driving the project could be, for instance, related to **market, environmental, and/or socioeconomic aspects of microgrids** (MENDES and NIGMATULINA, 2020). These projects follow a model where the ownership of DER is split from the ownership of the microgrid's distribution assets. In that way, DER procurement, deployment, and O&M take place **in a competitive context,** which is in line with emerging microgrid policy and regulatory trends. The grid operator/utility remains tasked with assuring proper O&M of the distribution wires interlinking the DER.

5In either of the above cases, the way grid operators/utilities recover their project costs is through rate-based mechanisms. In such schemes, the project's CAPEX is (most often) dispersed along the entire customer base of the utility (in the form of **additional tariff fees**). The approach stems from the historical role of utilities in investing in reinforcements to its own infrastructure **to meet basic service obligations** (AEE 2017). Given these upgrades are considered to benefit all customers, they become eligible for a generalized cost coverage. For the project to take shape under this framework, it generally needs to be formally recognized as a T&D infrastructure upgrade among the traditional range of reinforcement possibilities (transformers, poles, wires, meters, etc.). The agreement to such a status comes from the competent regulator, albeit not always their decision has favoured utilities. Following negative verdicts from utility commissions, some operators have limited the extent of the cost recovery to the customers directly served by the microgrid. In other occasions, the projects were halted or deemed inviable.

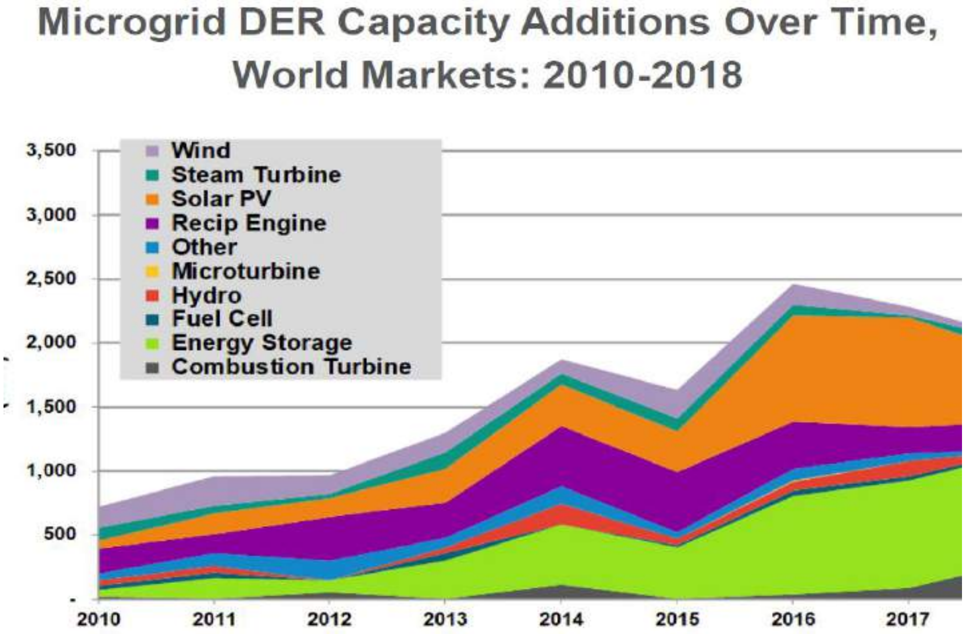
7.4 STATUS AND PLAN OF MICROGRID DEVELOPEMENT, BY COUNTRY

This section is taken from the overviews at the beginning of each regional session of the *https://microgrid-symposiums.org/*

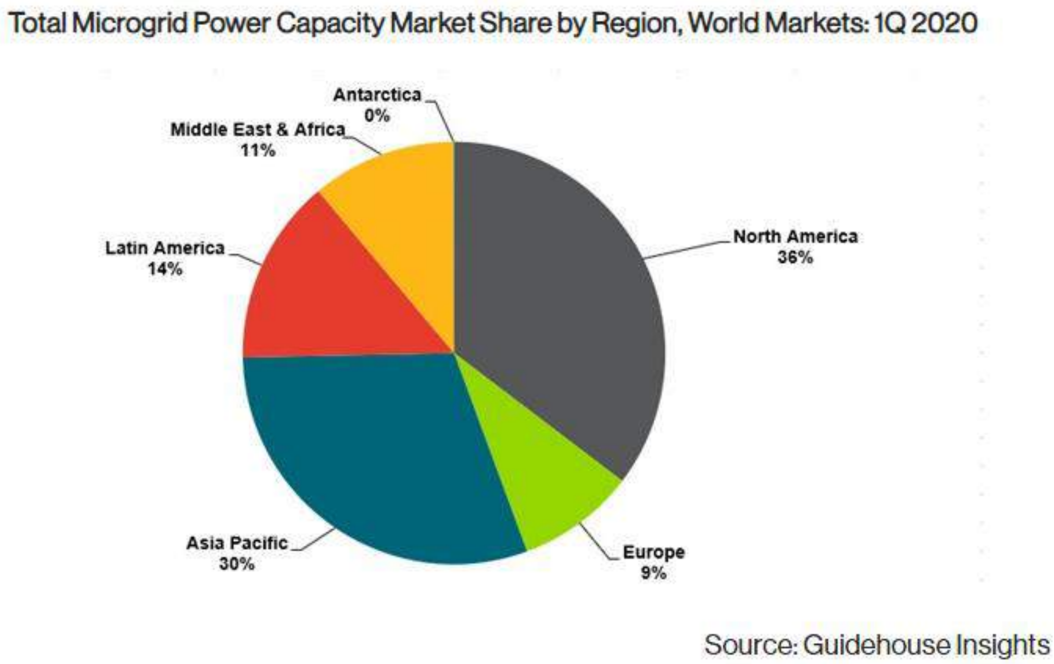
7.4.1 World overview

7.4.2 Microgrid development has reached more than 2 GW annual power increase

The yearly addition of RES in microgrid is significant, about +2 GW/year!

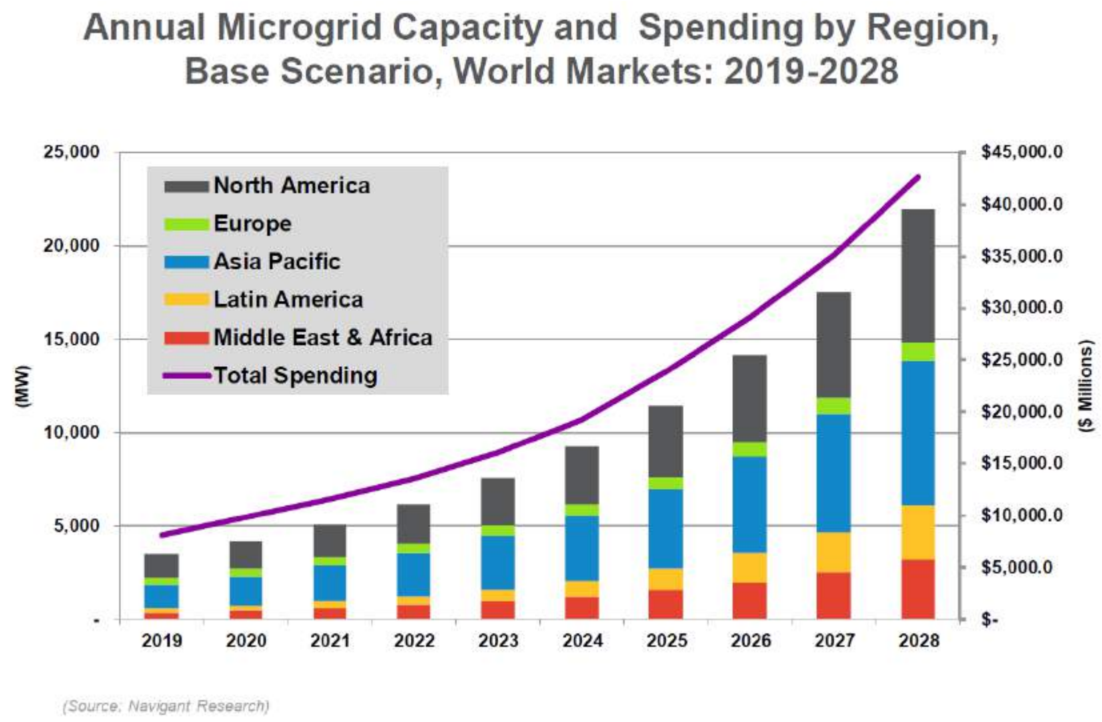


7.4.3 World overview: Asia PACIFIC & North America are market leaders in microgrids



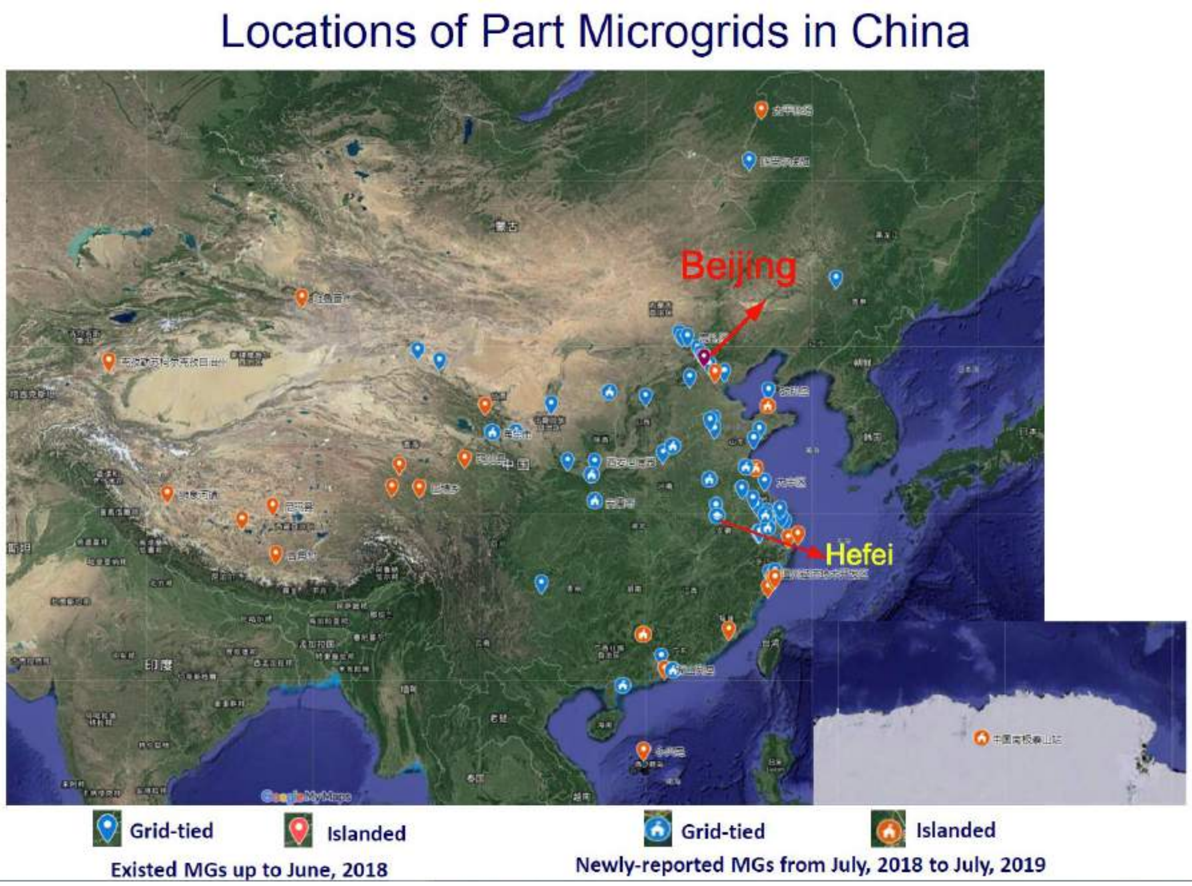
Source: https://guidehouseinsights.com/news-and-views/microgrid-deployment-tracker-identifies-2179-new-projects

7.4.4 Europe takes an insignificant part to microgrids' development.



According to more recent reports from various consulting firms, North America and Europe market shares are expected to be overcome by Asia Pacific in the medium term.

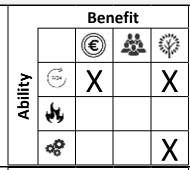
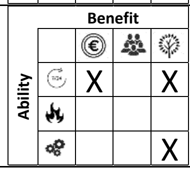
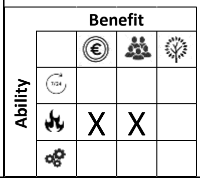
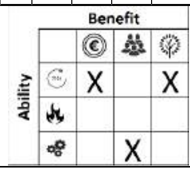
7.4.5 China is experimenting both islanded and grid connected microgrids

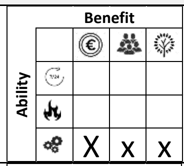
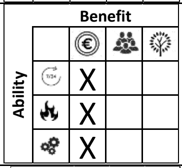
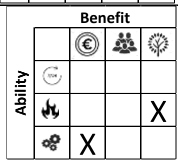
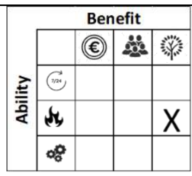
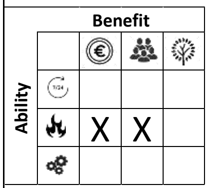
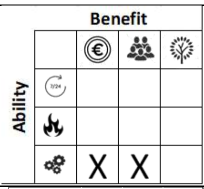
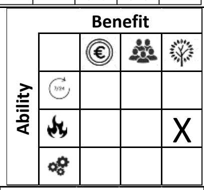
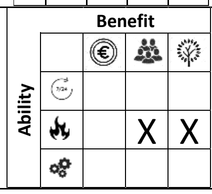


Source: Overview of Asia and Oceania Microgrids

7.5 MICROGRIDS' EXAMPLES DISCUSSED WITHIN THE WORKING GROUP

7.5.1 List of the studied projects

Studied Project x	Ownership	Business Model	Regulation	Magic Matrix
<u>Islanded microgrids</u>				
South Corea Islanded microgrids	Local government	Reduce fuel consumption and carbon emission	No dedicated regulation for microgrid	
Singapour Masera	N/A	to offer Affordable and Sustainable Electricity in Remote Areas	N/A	
Brazil Isolated communites	N/A	To provide reliable power supply **'Luz Para Todos'**	*N/A*	
Peru Alto Peru Project	Several NGOs from Peru	Electrification	No dedicated regulation	

Studied Project x	Ownership	Business Model	Regulation	Magic Matrix
<u>Grid-connected microgrids</u>				
USA Brooklyn microgrid	A benefit corporation formed by energy startup LO3 Energy	empower community members: more environmental & financial benefits	12-month regulatory sandbox pilot program	
USA Philadelphia US Navy Yard	private	the **least-cost solution** was to add gas engines and demand response arrangements to balance the local grid	N/A	
USA Bronzeville Microgrid	Asset-based distributed ownership, between ComEd and Enchanted Rock	*Multiple third-party-owned with no upfront costs, recoverable via rate payments in ComEd territory*	*Utilities commission did not approve project until ownership became distributed, and cost recovery element, was a challenge (not allowed in other US states)*	
USA, MD Gaithersburg Public Safety Headquarters (Montgomery County)	Duke Energy owns the assets, whereas O&M is shared with Schneider Electric	Public-private partnership (public facility) with Maas model (no upfront costs)	*Resulted from state plan for disaster preparedness and PPP status greatly facilitated navigating through regulation hurdles*	 *JEAN*
USA Woodbridge	N/A	improve resiliency	public grants	
Israel Maale Gilboa microgrid	Disclosed ownership for: - MG EMS - Grid & RES	Demonstrator	authorization to act as a local distribution utility for the Kibutz	
France Lerins microgrid Nice Grid	DSO Owned & operated	Demonstrator No profitability	No dedicated regulation	
France Corrèze Resilient Grid, France	DSO Owned & operated	Demonstrator No profitability	No dedicated regulation	

7.5.2 South Corea, Gasa island

Source : Woo-kyu Chae, et al, 2015, Design and Field Tests of an Inverted Based Remote MicroGrid on a Korean Island, energies, 8, 8193-8210

7.5.2.1 Where?

The project takes place on the Gasa island, in South Corea.

7.5.2.2 Raison d'être

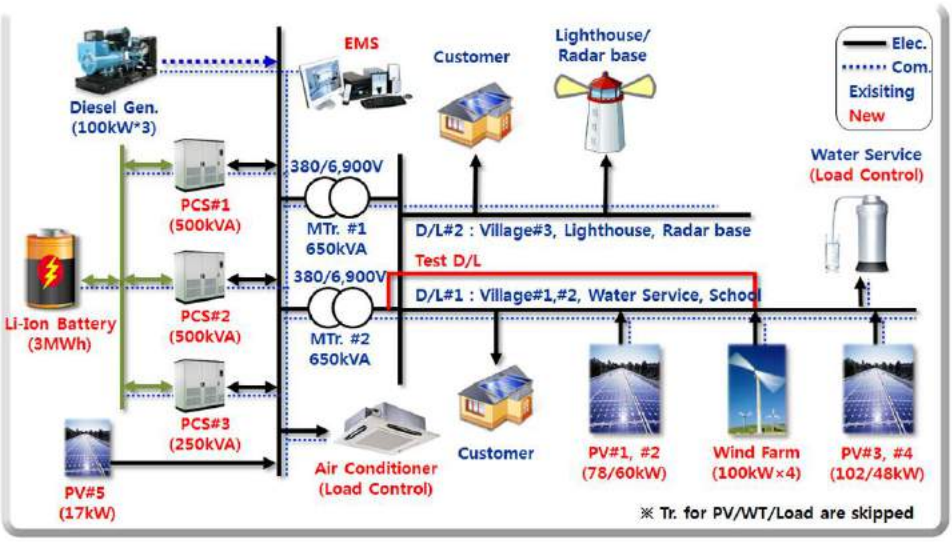
The *raison d'être* of the project is to let the Gasa island be an energy self sufficient island, with greener generation.

There are more than 120 diesel power plants which are being used to supply electricity to islands and not interconnected with main grid, in South Korea. Most plants were built more than 25 years ago so KEPCO(Korea Electric Power Corporation), municipal utility in South Korea and operating 65 diesel plants should replace old diesel generators. South Korean government wanted to replace old plants with renewable energies and ESSs and finally the project was launched in 2012.

Customers : 160 houses, 1 school, 1 health center, 1 church, 2 restaurants and 1 lighthouse spread over 6 km2.

7.5.2.3 Electrical description (loads, generation, storage, grid, services)

- DER
  - Wind Turbine Generator : 4*100kW
  - PV panel : total 314 kW at 8 locations
  - ESS : 3MWh
- Consummer : 200 consumers / 70~80MWh/month / 130~150kW
- Storage : 2*500kVA, 1*250kVA, 3MWh
- EMS : Yes. Developed by KEPCO



<System architecture of Gasa energy self sufficient island>

7.5.2.4 *Public contribution*

N/A

7.5.2.5 *Ownership*

Existing diesel power plant and distribution feeders are **owned by local government**.
And facility of microgrid such like renewable energy and ESSs are owned by **KEPCO**.
KEPCO and local government are trying to ensure that all facilities are owned by a single institute.

7.5.2.6 *Regulation*

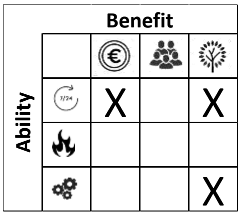
No dedicated regulation for microgrid.

7.5.2.7 *Value Creation and Business Model*

Reducing of fuel consumption, Carbon emission reduction

<Renewable energy complex of Gasa energy self sufficient island>

7.5.2.8 *Magic Matrix*



The main benefits of the project is to reduce fuel emission and deliver a good quality of supply.

7.5.3 Singapour, Masera

7.5.3.1 Where?

Semakau, 8 km South of Singapore, is hosting the **largest hybrid microgrid testbed and research platform** in Southeast Asia in the framework of the **REIDS project** (Renewable Energy Integration Demonstrator – Singapore), led by NTU and supported by the Singapore Economic Development Boardand the National Environment Agency. A consortium of French industrial partners have signed a four-year Research Collaboration Agreement with the University NTU to develop the MASERA microgrid testbed, with the support of the French DSO Enedis. Addressing the needs of a new and fast growing value segment for electricity utilities, **microgrids are today a key technology for rural electrification**. All over the world, many isolated, under-electrified and rural areas can rely upon microgrid solutions to support their economic development while limiting environmental impacts.
In this context, **MASERA** R&D testbed aims a developing a **fully integrated microgrid**, easily deployable, reaching local needs with an affordable electricity production cost.

In the framework REIDS microgrids demonstrators cluster led by NTU (Nanyang Technological University)

7.5.3.2 Raison d'être

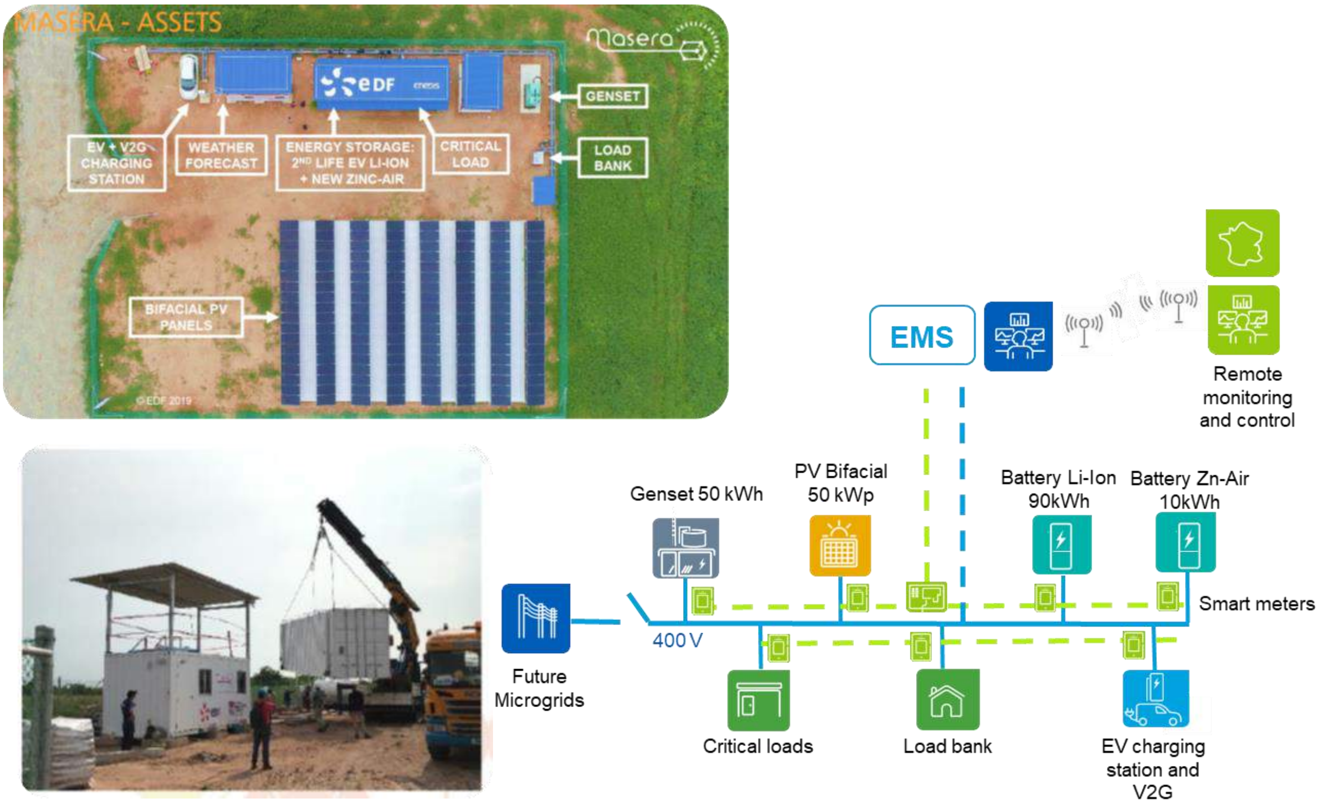
The *raison d'être* of the MASERA Microgrid project is to offer Affordable and Sustainable Electricity in Remote Areas. MASERA is:

- A **fully operational** microgrid deployed in only **one year**: basic & detailed designs, procurement, delivery, EPC, commissioning.
- Objective to demonstrate a **pre-commercial microgrid solution.**
- Overall **low-cost** and design to cost approaches.
- Hybrid and **decarbonized** microgrid for rural electrification.
- **Innovative** and **industrial** solution with **R&D objectives** (2nd life, design to cost, DERMS…).

7.5.3.3 Electrical description (loads, generation, storage, grid, services)

MASERA in key figures:

- 14 industrial partners
- 1 year deployment
- 100 kW installed generation
- 100 kWh storage
- 200 eq. households in an Indonesian village
- 24/7 monitored from France



7.5.3.4 *Public contribution*

Singapore Economy Development Board[7] has contributed to the funding of the MASERA microgrid via its support to the global REIDS initiative (cf section **Erreur ! Source du renvoi introuvable.**)

7.5.3.5 *Ownership*

This microgrid's assets are owned jointly between EDF and NTU.

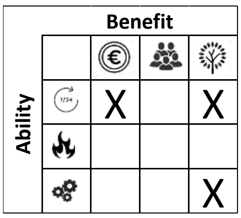
7.5.3.6 *Regulation*

This microgrid is a R&D testbed with no real customers connected and with no connection to the national grid. The Singaporean electrical regulation defined by the national energy regulator[8]required nevertheless this microgrid to apply for a mandatory "supply installation license".

7.5.3.7 *Value Creation and Business Model*

No profitability is expected from this microgrid but it represents a long-term investment for EDF that is using it to develop and test new technologies (e.g. innovative batteries, energy management system…).

7.5.3.8 *Magic Matrix*



The main benefits of the project is to bring electricity in an island, reduce fuel emission and deliver a good quality of supply.

[7] https://www.edb.gov.sg/
[8] https://www.ema.gov.sg/index.aspx

7.5.4 Brazil, isolated communities

7.5.4.1 Where?

The Iberdrola Group subsidiary 'Neoenergia' is entitled to serve 120.000 people in rural areas in the **State of Bahía**. The microgrid scheme is being deployed gradually, starting with six small villages in this State.

7.5.4.2 Raison d'être

In 2003, the Brazilian Government launched the 'Luz Para Todos' program, which seeks to **provide access to electricity** to 12 million people who live without it, 10 of them in rural areas. Electricity distribution companies are responsible for accomplishing this task, either by conventional solutions such as grid extensions, by individual generation solutions or by community-based generation solutions (microgrids).

7.5.4.3 Electrical description (loads, generation, storage, grid, services)

According to the requirements of the **'Luz Para Todos'** program, **the optimal microgrid design contains PV panels, a Diesel Generator, li-ion batteries and a converter,** whose sizes vary in regard to the size of the village.

7.5.4.4 Public contribution

The microgrid deployment plan has been approved by the Brazilian Regulator, ANEEL, which will be in charge of retributing power companies for developing the necessary infrastructure to serve society.

7.5.4.5 Ownership

As a regulated utility, Neoenergia will own and operate the microgrids, as part of its regulated asset base.

7.5.4.6 Regulation

As indicated in 7.5.5.2., this initiative has been fostered by the Regulator, who has set the microgrids requirements in order to provide customers with good quality of supply and reliability.

7.5.4.7 Value Creation and Business Model

Internal studies have demonstrated that a microgrid scheme is more cost-efficient than traditional grid infrastructure deployment. In fact, it yields better results in terms of quality of supply.

7.5.4.8 Magic Matrix

		Benefit		
Ability				
		X	X	

This microgrid project **provides reliable power supply** *to areas that need highly resilient systems due to their location. It has also important social benefits because it electrifies areas that didn't have energy access previously.*

7.5.5 Peru, Alto Peru Project

7.5.5.1 Where?

The Alto Peru was developed to provide electricity on a small village in **andean mountain**, very far from peruvian's central network.

7.5.5.2 Raison d'être

The aim was to **promote access to electricity** in the region of Cajamarca, located in the north of the Peruvian Andean highlands and one of the poorest areas in the country, with almost one million people living under the national poverty line, and having the lowest **electrification rate: 40.2%.**

7.5.5.3 Electrical description (loads, generation, storage, grid, services)

B. Domenech et al. / Energy for Sustainable Development 23 (2014) 275–285

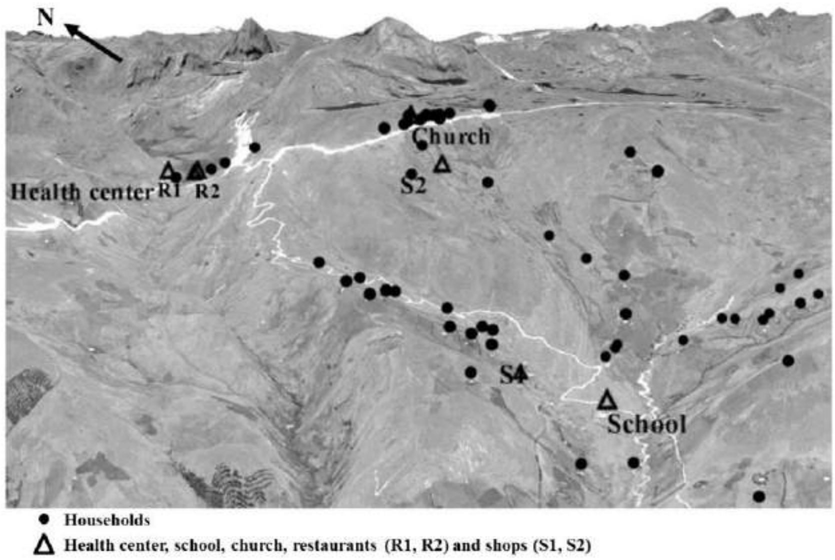


Fig. 1. Location of the consumption points in the community of Alto Peru.

Source : Domenech, Bruno, Laia Ferrer-Martí, Pau Lillo, Rafael Pastor, and José Chiroque. 2014. "A Community Electrification Project: Combination of Microgrids and Household Systems Fed by Wind, PV or Micro-Hydro Energies According to Micro-Scale Resource Evaluation and Social Constraints." Energy for Sustainable Development 23: 275–85.

- Customers:
  - 58 houses, 1 school, 1 health center, 1 church, 2 restaurants and 2 shops spread over 20 km2.
  - The households, the restaurants, the church's and the shops' demand is**: 280Wh/day**: power of around 200 W and an autonomy of 2 days
  - **Health center 975 Wh/day** of energy, 600 W of power and 2 days of autonomy.
  - **For the school 975 Wh/day** of energy, 1 000 W of power and 2 days of autonomy.
- DER (12 kW)
  - 4 x 1 200 W Wind Turbines
  - A 2 000 W hydroelectric power plant
  - Eight - 95 W PV panels
  - forty-one 95 W PV panels
- Storage: Batteries (4 types). Capacity: 1 500, 1 800, 2 400 and 3 000 Wh developed only in support of PV and Wing generation.
- Dispatch management: On some side, because of distance between consumptions points, but also of bad relationship between users, **autonomous PV panels have been installed**. On other side, as with school and health center, agreement have been previously made between actors. But, after project development and ex-post evaluation, it was decided to implement a **tariff-based control consumption strategy**. But **because this strategy was also not reliable, NGO-PA has developed training to sensitive to the needs to share electricity on micro-grid.**

7.5.5.4 Public contribution

7.5.5.5 Ownership

Several NGOs from Peru, Spain and USA as (Practical Action (PA), Engineering Without Borders, Green Empowerment) and Research Group on Cooperation and Human Development of the Universitat Politecnica de Catalunya had developed the « Program for Rural Electrification and Access to Renewable Energies in the Andean Zone » from 2007 to 2011.

7.5.5.6 Regulation

No regulation on this area which has the lowest electrification rate in Peru.

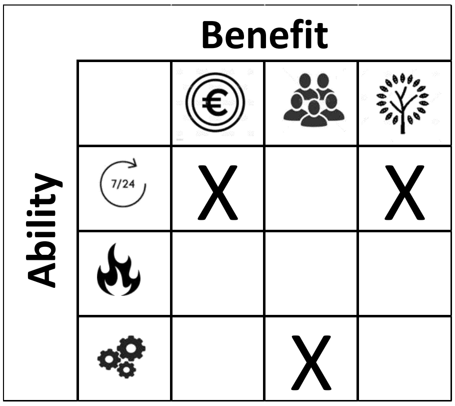
7.5.5.7 Value Creation and Business Model

- *Business model*: Social focus. Development of a solution with giving autonomy to the users at the end.
- *Value Creation proposal:* Social and economic development of isolated area on developing countries.
- *Ease of implementation and management*: The ease of management have been considered as social criteria, with a weight-criteria to 3 on 10.

7.5.5.8 Magic Matrix

The Magic Quandrant is based on 3 axis:

- Reliability & econcomics: Introduce **electricity access** thanks to multi-energy renewables sources.
- Reliability & environmental issuses: the generation is green
- Efficiency & Local & Social:
  - Development of **reliability** for the **two restaurants w**hose mains customers are miners working in the area and the two shops which provide essential goods in the town.
  - Help to development and **reliability** in keys **building of the community (church, health center, school).**



7.5.6 USA, Brooklyn microgrid, New York

7.5.6.1 Where?

USA, New York, Brooklyn.

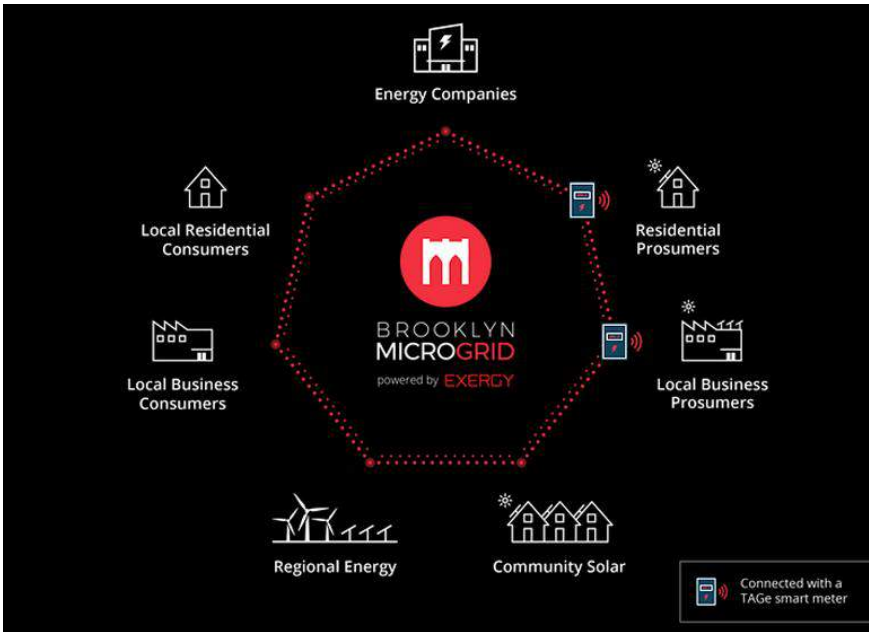
7.5.6.2 Raison d'être

The purpose of Brooklyn microgrid is came after having suffered the consequences of Hurricane Sandy. Thus, Brooklyn Microgrid emerged, reinventing the traditional energy grid model and introducing the concept of a community energy grid using blockchain technology for peer-to-peer trading to exchange and sell locally between consumers and prosumers.

7.5.6.3 Electrical description (loads, generation, storage, grid, services)

The microgrid, created in 2015, has more than one hundred consumer participants who can buy energy from the community corporation.

Now there are over 50 homes and businesses within the grid generating solar power. LO3 Energy fit prosumers with a TransActive Grid element (TAG-e) device. The device contains an electric meter and a computer connected to the WiFi network at home. The meter will measure production and consumption of energy while the computer will share this data with other TAG-e devices in the neighbourhood.



7.5.6.4 Public contribution

None

7.5.6.5 Ownership

Brooklyn Microgrid is a benefit corporation formed by energy startup LO3 Energy, with a mission to develop new energy models, support the local community, and promote clean energy.

7.5.6.6 Regulation

In terms of regulation, New York State regulations have been a barrier to a wider or fuller expansion of the program because only utilities and retail service providers are allowed to buy and sell energy under New York State's regulatory regime. For this reason, one of the partners, LO3 Energy, is moving ahead with a 12-month regulatory sandbox pilot program to test the concept of energy trading among consumers using a version of blockchain technology, excludes utility companies from its structures. The pilot program will allow participants in the microgrid project to trade energy attributes on LO3 Energy's software platform, with the main objective to build a cleaner and more sustainable environment.

7.5.6.7 Value Creation and Business Model

Business Model: This project has been selected to compete in $5m U.S. Energy Dept program to open up new opportunities for solar power.

Value creation proposal: Social focus, this project aims to empower community members to generate, store, and sell energy from the photovoltaic installations to other community users, providing the former with financial and environmental benefits.

7.5.6.8 Magic Matrix

The Brooklyn project offer the possibility of prosumers to trade energy directly in peer-to-peer, creating an improved economic efficiency.
It also empower the local communities and contributes to an increased green generation.

		Benefit		
Ability				
		X	x	x

7.5.7 USA, Philadelphia US Navy Yard

7.5.7.1 Where?

USA, Pennsylvania, Philadelphia

7.5.7.2 Raison d'être

The Philadelphia NavyYard microgrid was developed to connect the formerly US Navy-owned shipyards facilities (total surface: **490 ha**) to the **PEPCO utility distribution grid**. The decision to implement distributed generation and energy management system was taken after a thorough cost-benefit analysis that demonstrated that **the least-cost solution was to add gas engines and demand response arrangements to balance the local grid.** Environmental considerations were also factored in the detailed planning phase. The microgrid is also bidding on the PJM market to trade electricity.
The Philadelphia NavyYard website provides more detailed information:

7.5.7.3 Electrical description (loads, generation, storage, grid, services)

3 connections to the PEPCO distribution grid (the substations pre-existed before the project started in 2015). Total import capacity from PEPCO grid is 36 MW.
Generation capacity: 4*2MW gas engine peakers + 0.75 MW of rooftop solar PV
Maximum load: 30 MW
Battery Storage System: 1.5MW
Public EV charging infrastructure deployed across the campus.

7.5.7.4 Public contribution:

None.

7.5.7.5 Ownership:

Privately owned by PIDC, Philadelphia's public-private economic development corporation. Public and private investors list can be found here: *https://www.pidcphila.com/knowledge-and-networks/partners*

7.5.7.6 Regulation

Federal and Pennsylvania State microgrid regulation applies.

7.5.7.7 Value Creation and Business Model

Economic focus, aiming at attracting business in a redeployment area of the city of Philadelphia.

7.5.7.8 Magic Matrix

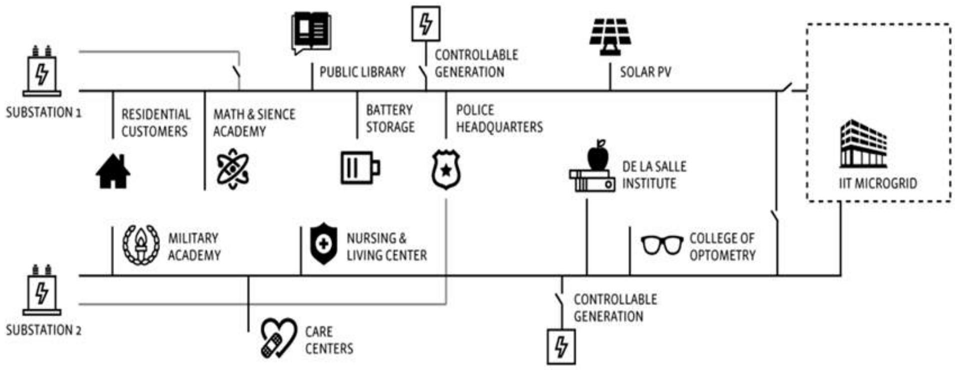
Magic Matrix to add as follows:

		Benefit		
Ability				
		X		
		X		
		X		

7.5.8 USA, Bronzeville Microgrid

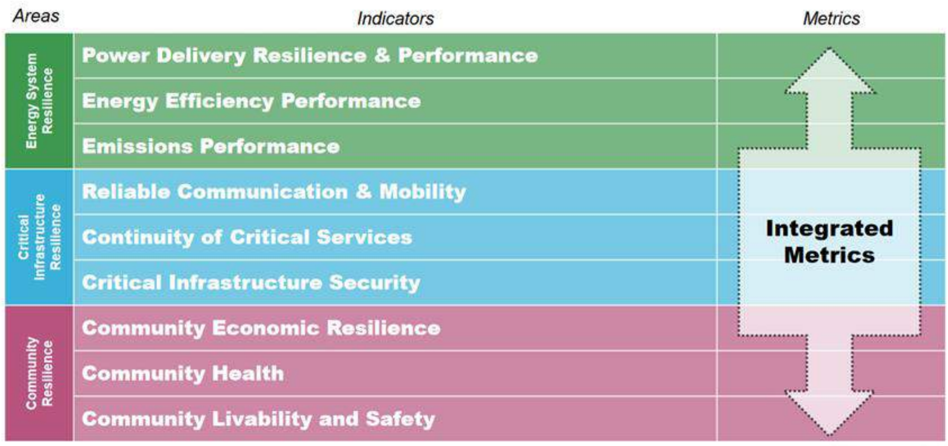
7.5.8.1 Where?

Bronzeville Neighborhood in Chicago, Illinois. includes more than **1,000 mainly residential** and small commercial customers, of socially/economically-vulnerable communities. Microgrid will serve **10 community facilities** in the Bronzeville of **Chicago**, including the Chicago Police Department headquarters, a fire station, the De La Salle Institute and the IIT Math & Science Academy, a library, public works buildings, restaurants, health clinics, public transportation, educational facilities, and churches.



7.5.8.2 Raison d'être

There are different orientations for the project. One the one hand, just like with other utilities, ComEd wants to tackle and **experiment microgrid** models within their service territory, which it considers "a benefit to local customers as well as to the entire grid". ComEd has marketed the Bronzeville microgrid to the utilities comission as a **grid modernization action**, thus enjoying the same status as regular power system upgrades. Then, part of the motivations are related to the utility wishing to expand their breadth of market opportunities. Reportedly, ComEd also wants to develop both technical equipment and components (own microgrid controller) and comprehensive integrated metrics for resilience, including "**community resilience**". In addition, there is a research and innovation goal, via the integration with the IIT microgrid, which is a vessel for microgrids research nationwide and internationally. Lastly, by offering non-uniterrupted supply to various critical customers (e.g. police and fire station), the microgrid clearly also provides a public service.



7.5.8.3 Electrical description (loads, generation, storage, grid, services)

Deployment will take place in two phases (25 MW load, and 45 MW load, respectively), in total amounting to:

- 750 kW solar PV;
- 2 MWh Lockheed Martin GridStar™ lithium-ion batteries;
- 7.7 MW natural-gas based DER;

- Development of ComEd’s microgrid controller, Siemens management software.

The microgrid connected to an existing microgrid at the Illinois Institute of Technology (with research and development purposes), which is centered around a combined heat and power unit but also developed with resilience in mind. This project creates the first “microgrid cluster” in the country.

7.5.8.4 Public contribution

US-DOE has co-financed the Bronzeville Microgrid, which on the other hand only came to life due to the regulatory approval from the utilities commision. The commission attended to the argument from ComEd that through its resilience capabilities, the project was in the public interest. The remainder of the upfront cost, which was supported by ComEd is paid back by ComEd’s customers.

The US DOE grant for this project was of $4 millions, out of a $25 millions’ total cost.

7.5.8.5 Ownership

This is an asset-based third-party owned type of microgrid. Enchanted Rock (private party) will own the DER assets, but ComEd owns the overall of electic distribution assets of the microgrid.

7.5.8.6 Regulation

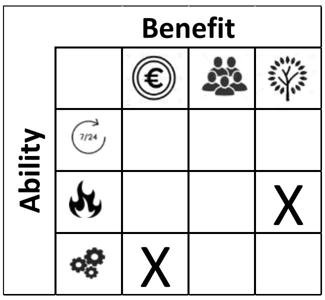
The project has been contentious from the beginning, given that electric utilities generally cannot own generation assets (this was ComEd’s initial intention) and due to the cost-recovery model in place. But based on public interest grounds, the state’s regulatory commission ended up approving the project. However, in other states, such as Maryland, such models continue to be denied by the respective utility commissions.

7.5.8.7 Value Creation and Business Model

The Bronzeville Microgrid is a project that generates multiple value streams, not all of them financial. The added value for surrounding communities is clearly substantial, given the fact the microgrid may operate as a **public-purpose shelter** and will contribute for critical providers and first responders to continue running in case, for example, of a natural disaster. There is also social value to the project, in the sense that it pertains to a socially-vulnerable area of Chicago, benefiting directly those customers who generally would not be able to afford DER assets independently. At the same time and based on ComEd’s argument, the project will help further develop microgrids through the technologyot innovation it provides, both for the state and nationally.

In terms of economics, the microgrid is deployed under **multiple third-party funding** with governemnt support (special case of asset-based distributed ownership), and through a **Microgrid as a Service (MaaS)** business model, In this sense, no customer bears the cost of deploying the microgrid assets at the onset of the project. Also, no financial amounts are disclosed, but it is known that widespread rate-based recovery models are usually sucessful in returning the upfront cost back to an investor, and this will likely be the case for ComEd. No details are also known publicaly as to how the relation between Enchated Rock and ComEd will work throughout the project, but it is likely that the assets have been directly sold and will be maintained by Enchanted Rock. On the other hand, indirectly, the project will deliver **added reliability value**; thus, by reducing outage frequency and durations in the area, ComEd will benefit from reduced budget spent in customer compensations.

7.5.8.8 Magic Matrix



The Bronzeville Project is first a **public-purpose shelter**, then a way to increase economical efficiency, rather than developing a line to face contingency situations.

7.5.9 USA, Montgomery county

7.5.9.1 Where?

Gaithersburg Public Safety Headquarters, which is a critical public facility in MD, USA. The onsite microgrid, now serving the county's largest building, will provide a significant amount of electricity — equivalent to that used by more than 250 homes.

7.5.9.2 Raison d'être

The project was born out of the county's concerns with the effects of a rapid changing climate and incresing **frequency** of debilitating **extreme natural events.** During the dramatic storm season of 2012, over 250,000 Montgomery County residents and 71 county facilities were without power for multiple days. The county then challenged industry with finding an innovative model that would allow the project to be financed with no or little upfront burden for the county, due to competing public budget priorities. The county has a clean energy innovative nature and wished to serve the public with modernized infrastructure and equipment, that would keep the lights on when storms and other events hit, while maintaining much necessary financial balance and security, as it is in the interest of its citizens,

7.5.9.3 Electrical description (loads, generation, storage, grid, services)

The following assets have been deployed by REC solar (A **Duke Energy** subsidiary) and **Schneider Electric**:

- **2 MW solar PV** mounted over the existing parking lot produces 3 million kWh per year;
- 800 kW Natural Gas CHP reciprocating engine;
- EV charging stations;
- Absorption cooling units;
- Schneider EcoStruxure™ microgrid controller system, which includes energy management with building automation system, and combined heat and power. This technology uses waste heat to efficiently make hot water and steam to heat or cool the buildings via thermodynamic processes.

The project also allowed capitalizing on the opportunity to undergo renovation of ageing low- and medium-voltage electrical infrastructure and gear.

7.5.9.4 Public contribution

Working with public customers is attractive for microgrid developers because it is a channel to **ameliorate the regulatory burdens otherwise faced by private undertakings**. At the same time, Montgomery County is still a paying customer; **the county will makes capacity and energy payments over the entire life of the microgrid.** Energy payments have a PPA-based locked-in rate, which eliminates market variability risks.

7.5.9.5 Ownership

The Montgomery microgrid configures the case of a **PPP** where the assets are owned by a private investor third-party. In this case, the capital investor is Duke Energy Renewables, an unregulated subsidiary of North Carolina-based Duke Energy. At the same time, while Duke owns the assets, the microgrid has been installed and will be managed with the assistance of Scheider Electric, novel business models' powerhouse and developer of energy management solutions for microgrids. REC Solar, a subsidiary of Duke, installed the PV systems and will operate and maintain them throughout the course of the project.

7.5.9.6 Regulation

The Maryland Public Service Commission has challenged various microgrid projects in the recent past. Those projects were utility-led and planned to expand cost recovery to all of Maryland customers. However, the commission has also expressed that it is in support of public purpose microgrids. The regulatory insight from this is that privately-funded, competitive microgrid undertakings involved with the public domain are clearly a **smooth regulatory avenue**, as they don't require such sort of commission approval, and remain in the interest of the general public.

7.5.9.7 Value Creation and Business Models

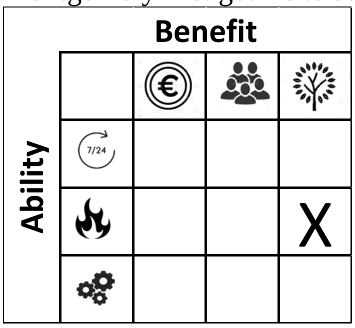
This project has widespread benefits, configuring a clear win-win-win; for Montgomery county, the benefits lie in the modernized facility and infrastructure, which will allow efficiently and resiliently handling future storm seasons, while assuring that critical public service and green development goals are met. The private players will see their returns consolidate across the years, via the **established PPA and LTSA**. They also benefit from the experience and the technology innovation steming from a project such as the Montgomery County microgrid, which will allow service cost reductions in the future. The county's citizens at large benefit from modernized, reliable, and by means of the sucessful financial scheme, affordable public service, which includes the reliable operation of some of its most critical facilities. Generally speaking, the

Gaithersburg microgrid project also offered numerous insights to the emergent microgrid community, by means of its business innovation and all-round pioneering nature.

In terms of business model, the project fits the category of a "**microgrid-as-a-service**" - MaaS, in which the public did not sustain any of the upfront costs, under a PPP scheme for the customer. The cost-recovery is via a PPA established between Duke Energy and Montgomery Country.

7.5.9.8 Magic Matrix

Montgomery first goal is to secure the resiliency of supply facing extreme weather conditions.



7.5.10 USA, Woodbridge

7.5.10.1 *Where?*

This microgrid has been deployed in Woodbridge, CT, USA.

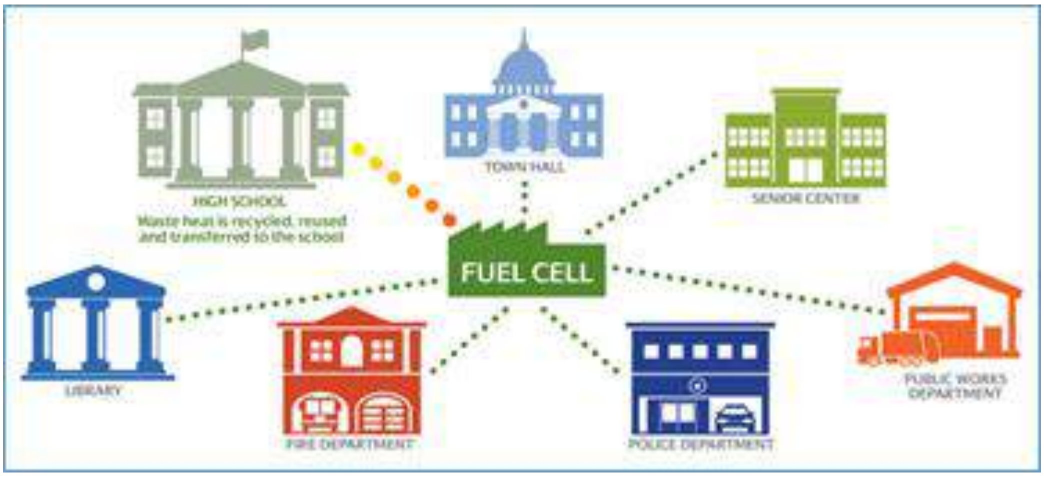
7.5.10.2 *Raison d'être*

The *raison d'être* of this microgrid is hardening **critical facilities** around the Woodbridge town center in the event that the main power grid fails. This area is prone to **storms**, which threaten the reliability of the electric grid.

7.5.10.3 *Electrical description (loads, generation, storage, grid, services)*

The project is composed of a 2.2 MW Fuel Cell Installed at Amity High School and uses waste heat for facility as a Combined Heat and Power (CHP) solution. This fuel cell can provide energy to the main grid when it is not working on islanding mode. Additionally, the Microgrid network uses underground infrastructure to increase resiliency, and maintains all existing overhead services. The Iberdrola subsidiary Avangrid is in charge of managing the microgrid infrastructure both in islanded and normal operation mode.

Customers: The selected seven critical facilities are Public Works, Town Hall, Police Station/Senior Center, Library, New Fire Station, Old Fire station, High School. These facilities will have priority in case of a grid failure.



7.5.10.4 *Public contribution*

The town has been granted $3M funding from Connecticut's Microgrid Pilot Program.

7.5.10.5 *Ownership*

Avangrid owns and operates the microgrid.

7.5.10.6 *Regulation*

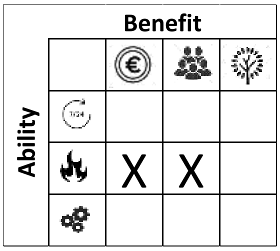
The regulatory environment made possible the development of this microgrid through public grants. There is still no regulation in place for microgrids in most states.

7.5.10.7 Value Creation and Business Model

Business Model: This project has been possible thanks to Governmental grants, which means the customers do not get an impact on their electricity bills for having this service.

Value creation proposal: Social focus, this project aims to provide power to the essential and most vulnerable facilities in the town in the event of an extreme weather event.

7.5.10.8 Magic Matrix



The Woodbridge project allows an **improve resiliency** against network faults or extreme weather condition, like storms. It provides value to citizens by improving the supply to the town facilities.

7.5.11 Israel, Maale Gilboa microgrid Pilot project (Elad)

7.5.11.1 Where?

Maale Gilboa is a kibboutz in Israel.

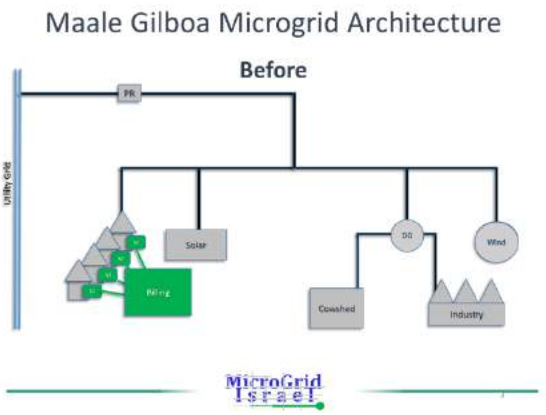
7.5.11.2 Raison d'être

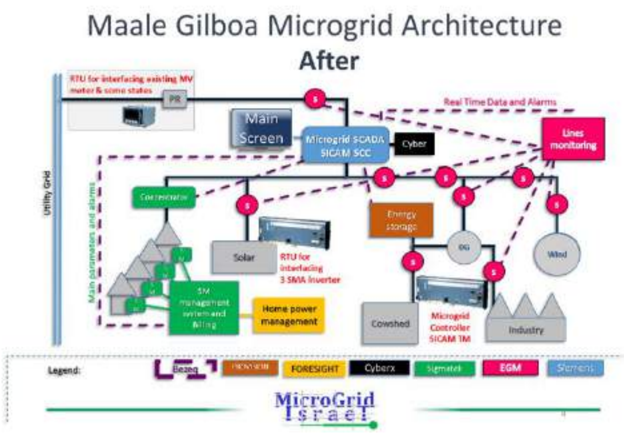
The aim of the project was to characterize, design, establish, operate and manage a microgrid system in a defined consumer area, in order to examine the technological applicability and benefits of operating such systems on a large scale. Emphasis was placed on optimal management of existing set of means used to generate, distribute, consume and save energy in an area defined as a closed system (energy island), which can be disconnected or connected to the main grid.

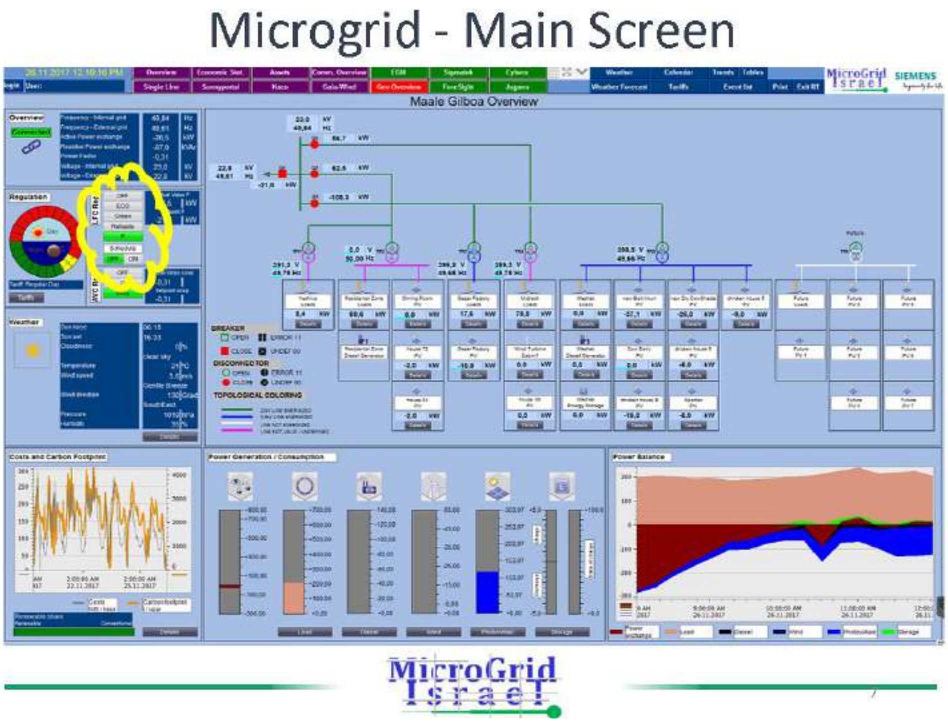
7.5.11.3 Electrical description (loads, generation, storage, grid, services)

Customers: A kibutz (special type of remote municipality), consisting of: 108 housholds, 1 industrial building, 17 agricultural consuming systems, 71 public elements, and stree lighting.

- *Description:*
  - Existing devices and charachteristics included:
    - Connection to the grid
    - 12 solar systems generating total of around 0.5MW
    - Emergency diesel generator
    - Small wind turbine
    - Overall yearly consumption around 3MWH
  - New deployed systems included:
    - Microgrid controller and smart controllers.
    - Microgrid management software.
    - Software for reporting consumption and costs.
    - Home and industrial smart meters.
    - Information security system
    - Measurement points on the internal network and in the various interfaces.
    - Elements and equipment for disconnecting / connecting from the grid.







7.5.11.4 *Public contribution*

Non available information

7.5.11.5 *Ownership*

Joint ownership. The ownership of the management and optimization devices were kept by Microgrid Israel (the microgrid development company), while the ownership of the local energy generation and network remained by the site owners.

7.5.11.6 *Regulation*

The project site obtained license for distributed generation sales to the grid, as well as an authorization to act as a local distribution utility for the Kibutz.

7.5.11.7 *Value Creation and Business Model*

Business Model: This project has been possible thanks to Governmental grants, which means the customers do not get an impact on their electricity bills for having this service.

Value creation proposal: The main goal was to examine the benefits of optimizing existing systems, explore possible benefits of intelligent operation of the system and quantify them as much as possible. Among the target potential benefits were:

- Improved efficiency of consumption due to loads shedding.
- The effect of providing recommendations to the home consumer to change consumption habits.
- Early detection and examination of faults at households.
- Equipment maintenance and operations alerts
- Alerts (in advance and not retrospectively) of reduced production capacity in renewable energy facilities.
- Benefit resulting from detecting phase imbalance.

7.5.11.8 Magic Matrix

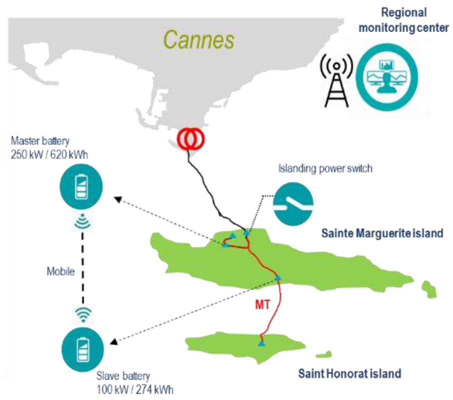
		Benefit		
		€		
Ability	7/24			
		X	X	

The Maale Gilboa project demonstrated that *intelligent operation presented the potential to save over 20% of the energy consumption, with the main items included:*

- ***Reducing losses** caused by phase load balancing*
- ***Improved monitoring** and maintenance of **renewable generation***
- *Comparable household **consumption education***

7.5.12 France, Lerins Grid Project

7.5.12.1 Where?



The Lerins Islands are located at the Mediterranean south cost of France, a few kilometers from Cannes.

7.5.12.2 Raison d'être

The *raison d'être* of the Lerins project was to demonstrate the technical ability of a DSO to switch a microgrid in real life, from connected to islanded mode, without disconnecting any customers.

7.5.12.3 Electrical description (loads, generation, storage, grid, services)

The Lerins Islands are **powered via an undersea cable connected to the mainland**. If this cable were to yield for whatsoever reason, the archipelago would then be cut off from any electric power supply, which represents the equivalent of the consumption of **400 customers** in the peak season.
Enedis and its partners have experimented the **use of batteries**, rather than generator sets, as a more environmentally friendly alternative.


DSO battery (Grid Forming Unit)


Islanding power switch

Accordingly, in the event of a power outage on the main grid, the **two batteries** installed on Sainte Marguerite island by the DSO and a third party immediately take over without a power outage for the customer thanks to the management system.

7.5.12.4 Public contribution

The Leirins micorgrid project is part of the European Interflex projet, which has received funding from the European Union's **Horizon 2020** research and innovation program under grant agreement No. 731289

7.5.12.5 Ownership

The Lerins Grid Projet is a DSO owned and operated microgrid.

7.5.12.6 Regulation

No specific regulation is established, as the Lerins Project is a demonstrator project.

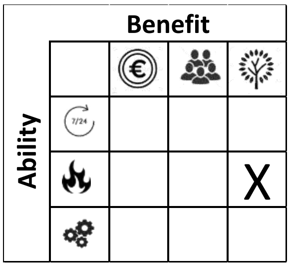
7.5.12.7 Value Creation and Business Model

Two major benefits were demonstrated:

- Improvement of **network resilience** :
    - **Islanding** of MT and LV distribution network), **without any power outage** for the customer
    - A **full-scale experiment** on a MV and LV electricity grid, with several distribution substations and several **batteries that communicate** with one another.
    - Reduction of **CO2 emission** (no use of diesel genset nor rotating machine)
    - Taking advantage from **new uses** connected to the distribution network, for network operation purpose
    - **Automatically** and remotely monitored
    - Complex preparatory phase and numerous precautions to **protect the environment** during the works (exceptional environment)
- **Multi-service** approach :
    - Use of **third party batteries** connected to the grid to increase islanding length
    - **Economic valorization** of the storage asset owned by the DSO by a market player (outside of islanding periods, a very rare event)

The **complex technical aspects** and **the cost of the solution** compared to the pristine quality of supply of the existing grid have lead the DSO Enedis to the following conclusion: further microgrids developments will **not be scaled up**.

7.5.12.8 Magic Matrix



The Lerins project improves the resiliency of the grid, especially during extreme outages or weather conditions.

7.5.13 France, Corrèze Resilient Grid)

7.5.13.1 *Where?*

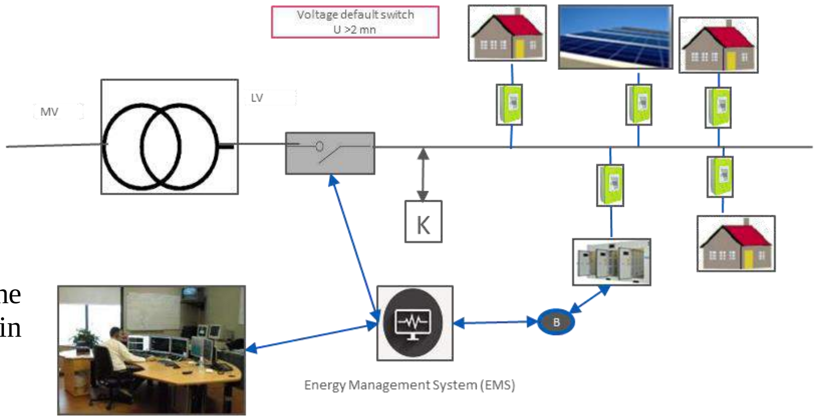
This microgrid is located in the hamlet of Nespoux, on the Millevaches plateau, in Corrèze, in the middle of France.

7.5.13.2 *Raison d'être*

The purpose of the project is to allow farmers and inhabitants of the countryside to use the energy locally produced by RES; to **improve the supply** and allow fresh start-up with local RENs generation and batteries in case of MV network fault.
In case of MV grid fault, the telecom network, the water supply and the inhabitants electricity supply are secured!

7.5.13.3 *Electrical description (loads, generation, storage, grid, services)*

- 58 km of MV grid, which of 25 km underground
- 588 LV customers for 1 MVA
- RES: 159 kVA of PV
- Storage with Li-ion battery 90 kWh



7.5.13.4 *Public contribution*

Public Contribution cover 80% of the cost of this 323 k€ project, achieved in October 2020.

7.5.13.5 *Ownership*

In France, the network and most of the components are owned by the Local Authorities, the *Syndicat de la Diège* in this case.

7.5.13.6 *Regulation*

Corrèze Resilient Grid is a demonstrator and is not covered by any regulation.

7.5.13.7 *Value Creation and Business Model*

The main value of the project is to allow the farmer to continue providing water and milking the cows when the MV grid is down. It also allows inhabitants to use cell phones.

7.5.13.8 *Magic Matrix*

For those reasons, the benefit of the Corrèze Resilient Grid Project comes from resiliency: powering shelters and face extreme weather conditions.

		Benefit		
Ability		€		
	7/24			
			X	X