Extension of the “Smart Micro Energy Cluster Test Bed”

Integrating the Tallaght Smart Energy Living Lab for Smart Grid and enerXchange Research

Supported by SEAI, as part of the 2017 SEAI RD&D call
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Executive Summary

The Tallaght Community Energy Living Lab is an energy research infra-structure with live consumers. It is developed by a partnership between South Dublin County Council (SDCC) and the Micro Electricity Generation Association Clg. (MEGA), and it is operated by MPOWER, a commercial subsidiary of MEGA. It has been supported by SEAI, EI and Corporate & Community Sponsors

The Living Lab is designed for research in energy production from low-carbon sources (solar, wind hydro etc.), harvested close to consumers ('distributed'), which involves active participation from those consumers to enable unconstrained distribution of the energy. Because it involves live consumers, it is suitable for a wide spectrum of research: technologies, consumer engagement, market and policy design, and consumer-oriented business models. Its primary focus is on '**Flexibility as a Service'**, or FaaS, a new term introduced by the Living Lab for the use of flexibility in distributed resources (e.g. Demand Response, batteries, thermal storage, hydrogen storage & power-shifting) as an alternative to slow and expensive grid upgrades to support local production.

MPOWER has a symbiotic relation with the Living Lab: MPOWER's technology, called **enerXchange**, powers the Living lab, while the Living Lab provides the ideal environment for research into technologies, business models and market changes for MPOWER's visionary and disruptive solution. That solution involves disturbance-neutral **Community Grids**, operated by regulated **Community System Operators** (CSO), a new market actor in addition to the TSO and DSO.

The development of the Living Lab has until now has been focussed on supporting a wide range of technologies. It features 200 prosumers, of which 80 fitted with MPOWER's smart metering, and 13 of them connected to the enerXchange Prosumer Dashboard via a LoRa communication infra-structure. On the production side, it features solar PV, a micro District Heating System, and a wind turbine. In South Dublin County Hall, a PV-powered microgrid is supported by a flexible Community Grid Stabiliser (CGS) that houses multiple battery technologies (Lithium-Ion, Lead-Carbon, ultra-capacitors, for a total of 300 kWh) and power quality equipment.

Future development of the Living Lab will more narrowly focus on distribution, specifically supporting the Community Grid and CSO concept. The scope of this project was to lay the foundation for this, by integrating the various parts in the Living Lab with enerXchange, in preparation for the full deployment and demonstration of an enerXchange prototype. That prototype is currently being developed by a DIT-led consortium which includes IERC, SDCC, and industry partners (MPOWER, Siemens Group, CRES, Systemlink, mSecmicon), and is supported by the International Energy Research Centre (IERC).

The three key findings from this project were:

- **LoRa is suitable for near real-time delivery of live data for rapid analysis**
- **Live data is critically important when engaging with communities**
- **Flexibility does facilitate the integration of more renewables**

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Background

The case for a Community Energy Living Lab

Most low-carbon energy is from renewable sources: energy stored in cyclic processes, which could be industrial (e.g. waste heat) but usually are natural such as sun, wind, tidal. The ubiquitous nature of natural processes brings production from these renewable sources closer to consumers, possibly even in their homes (e.g. roof-top solar). This is a paradigm shift from traditional large area energy systems, in which production is typically remote from consumers. This shift has proven to be quite disruptive, socially, economically and technically. Socially, communities do not always accept production within their midst, especially not if they are intrusive while offering little benefits to the community. Economically, the economies of scale of distributed production with many small, albeit often modular units that may be owned by individual consumers, e.g. roof-top solar, must compete with the economies of scale of today's increasingly large units (Larger Units which encounter sporadic community opposition). Technically, local production, especially from renewable energy sources that fluctuate more and are less predictable, creates more disturbances, both system wide (imbalances between supply and demand), as well as localised close to consumers.

To safely guide us through this paradigm shift, there is a growing realisation that communities are central to the solution. Policies are being introduced, in no small part because of the work conducted by MEGA, to incentivise active involvement from communities in the management of energy systems, both in Ireland[1] and Europe. This is demonstrated by the following quotes from recently published European regulations[2,3]:

- *"Local energy communities can be an efficient way of managing energy at community level by consuming the electricity they generate either directly for power or for (district) heating and cooling, with or without a connection to distribution systems. To ensure that such initiatives can freely develop, the new market design requires Member States to put in place appropriate legal frameworks to enable their activities".*
- *"Consumers are essential to achieving the flexibility necessary to adapt the electricity system to variable, distributed renewable generation. Technological progress in grid management and renewable generation has unlocked many opportunities for consumers, and healthy competition on retail markets will be essential to ensuring the market-driven deployment of innovative new services that cater to the consumers' changing needs and abilities, while increasing system flexibility. By empowering consumers to participate in the energy market more, and participate in new ways, citizens should benefit from the internal market in electricity and the Union's renewable targets should be attained."*
- *"Distributed energy technologies and consumer empowerment have made community energy and energy cooperatives an effective and cost-efficient way to meet citizens' needs and expectations regarding energy sources, services and local participation. Community energy offers an inclusive option for all consumers to have a direct stake in producing, consuming or sharing energy between each other [...] Energy communities should be allowed to operate on the market on a level-playing field without distorting competition. Household consumers should be allowed to voluntarily participate in a*

[1] http://www.dccae.gov.ie/documents/Energy%20White%20Paper%20-%20Dec%202015.pdf

[2] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on common rules for the internal market in electricity (recast), 2016/0380 (COD), Council of the European Union, 15 September 2017

[3] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the internal market for electricity (recast), Brussels, 30-11-2016, 2016/0379 (COD)

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community energy initiative as well as to leave it, without losing access to the network operated by the community energy initiative or their rights as consumers."

- *"Member States may decide, to grant energy communities with a right to manage distribution networks in their area of operation [...] If such right is granted, Member States shall ensure that: (c) [...] energy communities do not discriminate or harm customers remaining connected to the distribution system."*

The above regulations refer to active participation of communities in energy markets, not only in the production of energy, but also in the distribution of that production, and therefore should be enabled to participate in both markets. One cannot be considered without the other if the potential of local renewable energy sources is to be maximised (see also chapter: Societal Challenge). Policies also stress consumer choice i.e. local community initiatives to participate in these markets should not affect consumers within those communities who chose not to participate.

Enabling and incentivising market participation by consumers and communities in markets for production as well as distribution, while maintaining consumer choice is a major challenge. Critical for success is the positive impact on sustainability of communities, not just in terms of environmental benefits, which is especially important for urban communities, but also commercial reward. Given a target for renewable production of 66% by 2050, set in the European roadmap[4], and assuming much of that will be distributed, then a target of 50% for distributed renewable, community hosted production in 2050 is not unreasonable. Globally, no more than a trivial 2% was from distributed production in 2014[5], so there is enormous potential for growth.

Energy Roadmap 2050
"Climate policies for respecting carbon constraints to reach 85% energy related CO2 reductions by 2050 (40% by 2030), consistent with 80% reduction of total GHG emissions according to the economy in 2050"

Globally, electricity production in 2014 was 23,500 TWh[6]. The average wholesale price of production is around €45/MWh in the EU (slightly lower in US). The price of distribution (TuOs and DuOS), is approximately the same again. Assuming demand and the price of production stays flat, then the potential market for distributed production is €530B in 2050, an increase of more than €500B, or €14B year on year. Demand is likely to increase, if for no other reason that 1 Billion people still have no electricity, but the price of production can be expected to stabilise as renewable technologies become more competitive (PV almost is today). The potential for communities participating in markets for distribution is harder to quantify, since only a relatively small part of the TUoS and DUoS is channelled through such markets. That will increase as a result from the beforementioned regulations, but it is not yet clear by how much. If communities even get 25% of the revenue from distribution, only for production they host, then that represents €125B in 2050, or €3.5B year on year increase, assuming the price for distribution stays flat. In practice, it is important to note, the price for distribution is likely to increase as the share of renewable energy increases. It is therefore likely to be a much more dominant share of future retail prices.

So the commercial opportunity for communities to participate in markets for production, and especially in markets for distribution is substantial. But although communities often have 'community spirit', and do want a sustainable community, they also consist of individuals. To engage them such that they in concert with each other participate in these markets is challenging, despite the clear commercial opportunities. Engaging communities therefore requires research, even fundamental research, not just in technologies but also in social sciences, business models, policies and regulations. These are not easily conducted in small, tightly controlled labs: communities do not live in such places. The lack of a suitable research (adequately funded) infra-structure for such

[4] Energy Roadmap 2050, European Union, SEC(2011) 1565/2
[5] https://www.navigantresearch.com/research/distributed-energy-resources-global-forecast
[6] https://yearbook.enerdata.net/world-electricity-production-map-graph-and-data.html

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research, i.e. a Living Lab, has been a major barrier in the wider deployment of renewable energy, and consequently in realising the potential €17.5B (+) annual growth.

The Tallaght Community Energy Living Lab

In response to the emerging distributed energy market needs and the huge untapped market potential, the not-for-profit Micro Electricity Generation Association (MEGA), in 2012, formed a Technology Group (under the 2012 Action Plan for Jobs) incorporating 5 technology companies, and established a start-up, Smart M Power Co. Ltd. (t/a MPOWER). The immediate purpose was to enable the development of the Tallaght Smart Energy Test-Bed, which later became the **Tallaght Community Energy Living Lab**. This Living Lab is an energy research infra-structure with live consumers. Its mission was:

..to conduct research in energy production from low-carbon sources (solar, wind hydro etc.), harvested close to consumers ('distributed'), and that involve active participation from those consumers to enable unconstrained distribution of the energy.

As such, the Living Lab directly addresses the following SEAI-defined topic areas:

- **Renewable Electricity and Micro Generation.**
- **Distributed/ Local Decarbonisation of Energy Supply to Industry.**
- **Smart Grid and Energy Storage**
- **Community Energy Project Models and Structures.**
- **Accelerated deployment of innovative energy efficiency and renewable energy technologies**

The initial scope of the Living Lab was applied research into grid-supportive, distributed smart grid technologies. At its core was local power matching: matching local production with local consumption through prosumers offering Demand Response, and storage technologies such as batteries, thermal storage, hydrogen, power2gas. This has since evolved into MPOWER's disruptive Community Grid concept, which is described in more detail below, in chapter 'Community Grids'. The direct, active partnership of South Dublin County Council (SDCC) further expanded this to include energy efficiency solutions, primarily for buildings.
The first community was equipped in late 2013 with incorporating 20 Candidate Prosumers. Since 2013, MEGA in partnership with SDCC has since been further developing this Living Lab, supported by SEAI and EI, industry partners such as MPOWER, Siemens UK, Freqcon, Microsoft, Nissan, Enersol, Hybrid Energy Solutions, and academic partners: DIT, ITT. It is operated by MPOWER, and features:

- MPOWER's Prosumer Dashboard and Data Acquisition system
- 80 prosumers fitted with MPOWER's smart meters;

- 13 of which connected to a LoRa communication network;
- Micro District Heating system (µDH) in Glenasmole's GAA club;
- Roof-top solar PV at Glenasmole's Community Centre (3 kVA), as well as on the roof of the local school;

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- Solar PV powered microgrid at County Hall, with 50 kVA of roof-top solar PV, and a 300 kW battery array with Lithium-Ion, Lead-carbon and Supercapacitors, as well as other power quality equipment, known as the Community Grid Stabiliser (CGS), located at County Hall;

Several notable developments in the living lab are currently ongoing, such as a 2 MWe District Heating System in the centre of Tallaght which involves the Amazon data centre, and an in-stream hydro scheme in the Glenasmole White Energy community.

Community Grids

Community Grids is MPOWER's disruptive solution to engage communities and dramatically increase the share of renewable production hosted by communities. The Living Lab has played, and will continue to play an important part in the development of the solution. This chapter gives an overview of the concept.

Societal Challenge

The main task of grid operators (DSOs and TSOs) is to ensure the reliable and economic distribution of electricity from producers to consumers. That means maintaining power quality, i.e. a stable voltage, frequency, and unity Power Factor (PF) between Voltage and Current, at the Point of Sale (the main meter of the consumer). TSOs, who operate the high capacity (high voltage) Transmission System, maintain the system wide frequency. DSOs, who operate the low capacity (low voltage) Distribution System to which most consumers are connected, maintain voltage, power factor and frequency harmonics.
There are many conditions in the grid that could disturb these parameters, e.g. congestion and inverter switching. The objective of TSOs and DSOs is to keep these disturbances to an absolute minimum. To maintain this **disturbance-neutrality** in the Distribution System, DSOs ensure there is enough local distribution capacity (to avoid congestion), and grid-embedded specialised devices that respond, often semi-automatically, to local disturbances. It is these local disturbances close to consumers that is the focus of the Community Grid solution.

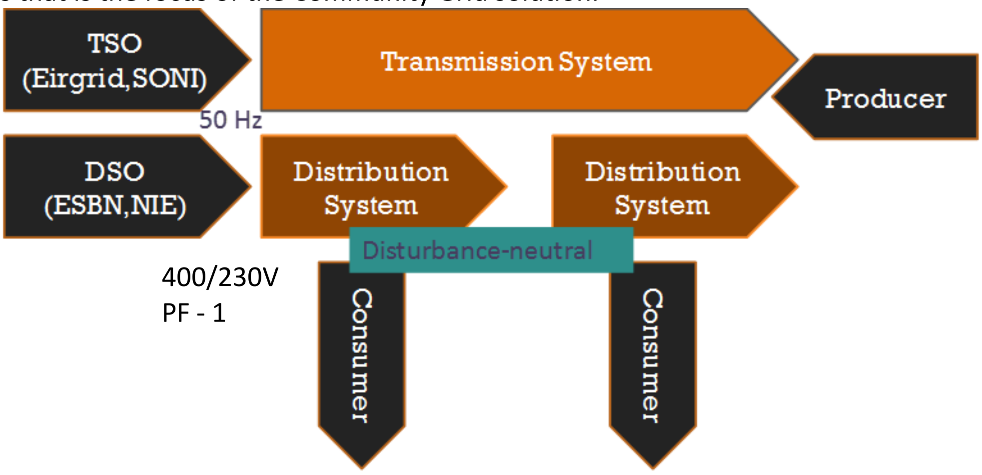

fig 1. Abstract model of the grid, with the main actors

Production close to consumers (distributed production) tend to increase disturbances, often makes them less predictable, and introduces new disturbances such as bi-directional flows (Distribution

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Systems were designed for power from remote producers, not from remote and local producers i.e. from anywhere). This is especially the case if local production is from renewable energy sources, which fluctuate more and are less predictable than traditional sources of energy. Maintaining disturbance-neutrality is thus becoming more challenging as distributed renewable production increases. Also, while the number of consumers in an area tends to change slowly, the production market is much more dynamic, moving much faster and much more granular than DSOs schedule to upgrade the grid, which are often planned years in advance. Waiting times for new grid connections are today measured in years rather than in weeks.

In this changing environment with more challenging disturbances and changing market dynamics, the current approach in which DSOs must upgrade the grid first before more distributed production can be allowed, no longer suffices. E.g. to allow for bi-directional flows, certain equipment in the grid, such as protection equipment and meters, must first be upgraded. As an example, NIE (the Northern Ireland DSO) limits the allowed aggregated installed capacity of production to the baseload in the area, to avoid power flow reversals. Consequently, assuming baseload is around 20% of average demand, the maximum allowed installed capacity for production is 20% of the average demand. If that production is from a renewable energy source like wind, which typically has a capacity factor of 30%, then on average only a maximum of 6% of the average demand can be produced locally, independent of how much wind potential there is in the area. With that approach, to increase distributed production substantially globally to 50% by 2050, almost all of the Distribution Systems that have this constraint (and that is most Distribution Systems) must be upgraded first before more production can be installed. That is a slow and expensive activity, delaying the potential for renewable energy sources and delaying the Energy Transition.

These challenges are recognised by the industry, and the widely accepted alternative approach is to use **flexibility** in distributed resources instead, i.e. resources owned by third parties (other than the grid operator). They respond to disturbances through appropriate distributed controls implemented in each of these resources. E.g. bi-directional flows can be avoided by making sure local consumption is always more than local production, using flexibility in consumption (also known as Demand Response) and/or other resources such as batteries. With this power matching, the maximum average local production can now be the same as the average local consumption, i.e. 100% rather than 6%, which is a massive improvement.

Using third-party flexibility to maintain disturbance-neutrality is not new. It is already used today by TSOs to balance supply and demand on a second by second basis, and apropos maintain a frequency of 50 Hz (because load sharing in the grid is done primarily by synchronous generators, imbalances disturb the frequency). Since TSOs themselves do not produce or consume energy, they must procure flexibility from third-party producers and/or consumers for this balancing. They procure this from so called Ancillary or System Services markets, or a more generally term would be **Flexibility Markets**. These are closely linked with wholesale **Energy Markets**, in which producers sell electricity to consumers. Energy Markets ensure a market equilibrium over defined trading intervals, typically half an hour to an hour each, which balances supply and demand over those intervals, but not within those intervals. For that, the TSOs procures flexibility from the Flexibility Market, but the amount of flexibility needed for a trading interval depends on how much supply and demand has been contracted in the Energy Market. Also, faster response within trading intervals, such as inertia, can often only be provided by resources already producing or consuming, i.e. that have already been contracted in the Energy Market (this notably does not apply to batteries).

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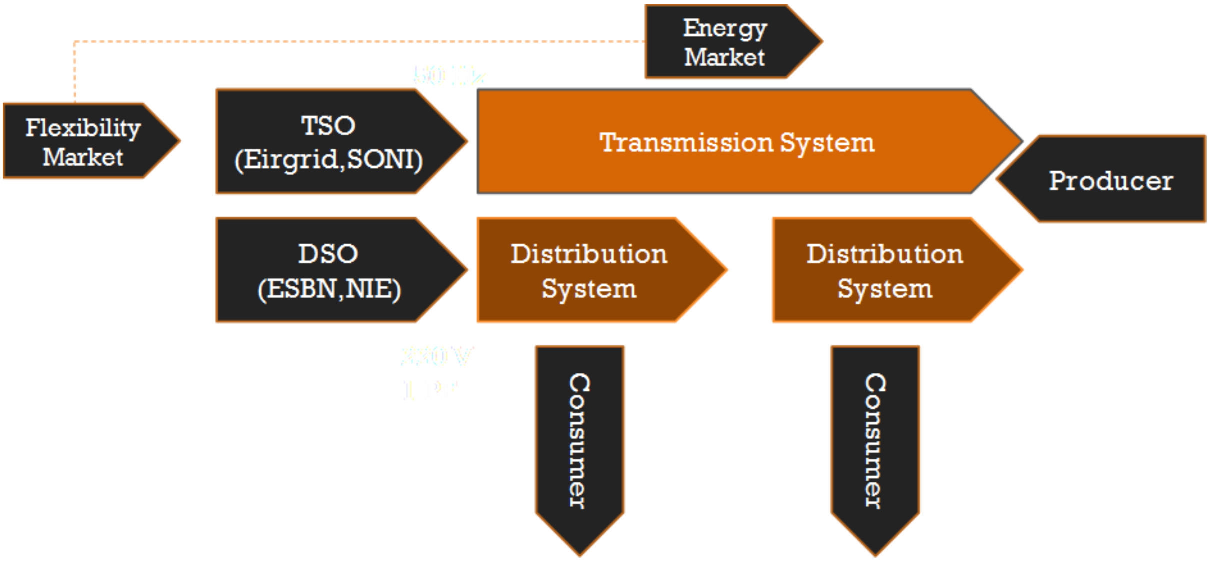

fig 2. Interlinked Energy Markets and Flexibility Markets

Interlinked Energy and Flexibility Markets could also be used for other disturbances than imbalances in supply and demand. Again, the TSO already does this for e.g. managing voltage in the Transmission System, but it can also be used for disturbances close to consumers. That requires these markets to be associated with the Distribution System, and thus the DSO rather than the TSO. However, while there are only a few dozen TSOs in Europe today, there are approximately 2,500 DSOs, each DSO an independent local monopoly, and many with a strong, locally regulated, consumer focus. The average TSO/DSO ratio is approximately 1:100 (Ireland/France being a very notable exceptions with a single DSO and a single TSO). This high ratio has resulted in a loose coupling between DSOs and TSOs, largely through relatively simple, standardised electrical interfaces at sub-stations. DSOs have no relation with the existing Energy or Flexibility Markets, and do not trade any services with consumers or producers, other than providing them with grid connections. This creates a natural inertia against changes that disrupts how DSOs operate, especially if it disrupts their currently loose relationship with the TSO, and especially if it needs to scale across DSOs to have sufficient societal impact. Local Energy and Flexibility Markets is such a disruptive change.

Community System Operators and Community Grids

To overcome the combined inertia of DSOs, MPOWER and MEGA, as a result from research done in the Tallaght Community Energy Living Lab, is proposing a new actor in the electricity supply chain: the **Community System Operator**, **or CSO**. CSOs autonomously i.e. with minimal interaction with the DSO, operate local Energy and Flexibility Markets and manage the relations with external (wholesale) Energy and Flexibility Markets.

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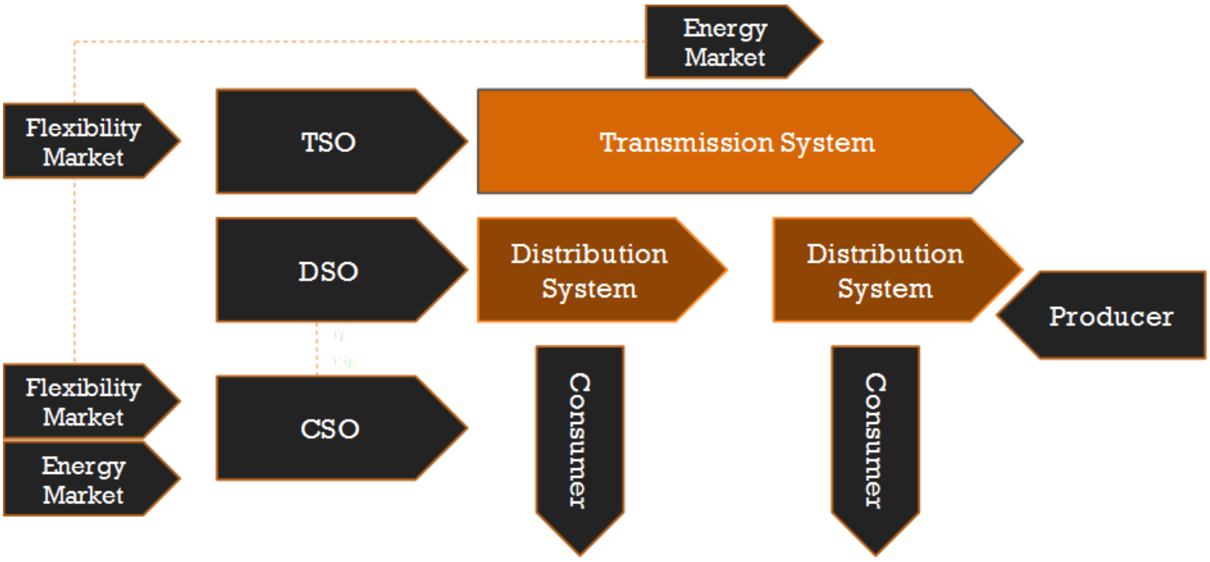

fig 3. The new actor: the Community System Operator, or CSO

Actors in these markets are local individual **prosumers**, and optionally independent local producers. Prosumers are consumers who are also producers and/or providers of flexibility, which is a slightly wider definition than the more commonly applied definition (a consumer who also produces energy).

Actors trade production and/or flexibility from resources they own, or 'assets' in market speak. MPOWER calls this group of prosumers and their assets a **Community Grid**, and the flexibility offered by these prosumers as **Flexibility as a Service**, or **FaaS**, a much more appropriate digital age term for Ancillary Services. The CSO operates autonomously from the DSO, and can therefore operate multiple Community Grids, in multiple Distribution Systems. This creates the scalability needed to create sufficient societal impact. Several Community Grids may operate within the same Distribution System, and each may be operated by a different CSO, providing competition.

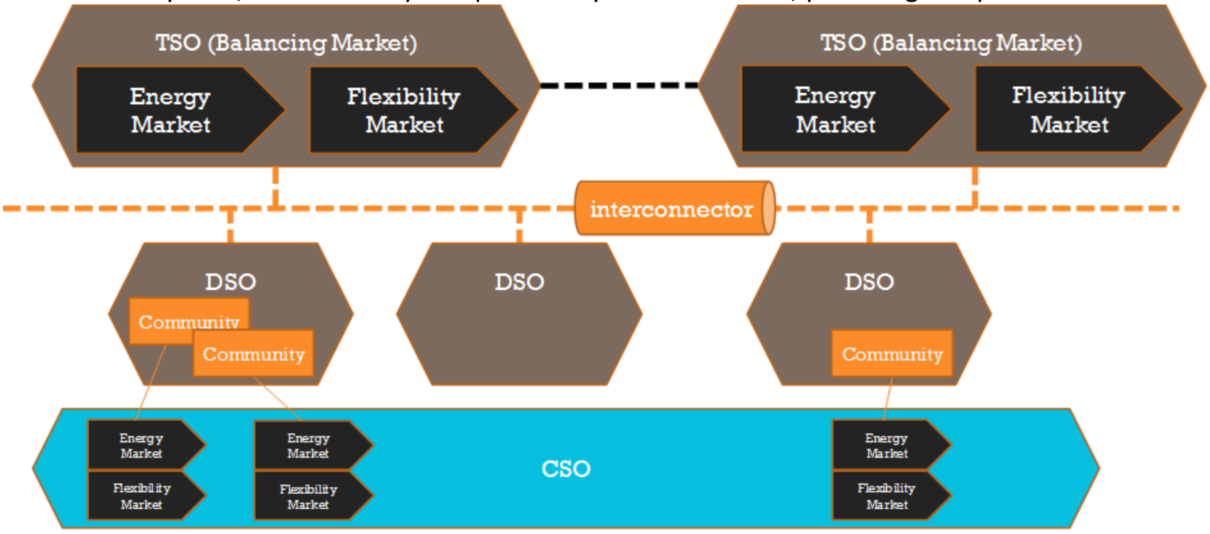

fig 4. A CSO may operate across several DSOs and even TSOs, but a Community Grid is always restricted to a single DSO.

Given that disturbances are a physical phenomenon, any Community Grid that does not include all assets in the physical area, cannot guarantee disturbance-neutrality when it is influenced by multiple connections, such as consumers connected to the same feeder. Instead, the combined actions of all CSOs operating in an area, together with the operations of the DSO, must ensure disturbance-neutrality. This requires an abstraction ('virtualisation') of disturbance-neutrality for Community

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Grids and how it relates to 'physical' disturbance-neutrality. This is where distributed, renewable production truly meets the digital, internet driven smart grid, in which logical abstraction is a well-known concept. It leads to MPOWER's working definition of a Community Grid:
A group of grid-connected electrical resources, within a clearly defined electrical boundary in the Distribution System (e.g. sub-station), interconnected through a logical connection point to the grid for which it acts as a single controllable entity to maintain disturbance-neutrality.
The observant reader will have noticed that this definition is very similar to the definition of a microgrid, as adopted by the US Department of Energy – That 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[7]."
Like microgrids, Community Grids manage a group of resources within clearly defined electrical boundaries, and like microgrids, Community Grids are a single controllable entity (without which it couldn't operate autonomously from DSOs). But there are some very noticeable differences:

- A microgrid must be able to island from the main grid, therefore it must have a single physical connection to the Distribution System, and this connection must be shared by all resources within the electrical boundary. In contrast, the resources in a Community Grid are each independently connected to the Distribution System, and the single connection to the grid is a logical connection, which does not have to be shared by all resources within the physical boundary. As a result, Community Grids cannot island.
- A Community Grid must maintain disturbance-neutrality on the (logical) connection with the Distribution System. The microgrid has no such obligation for its connection to the Distribution System, only within the microgrid (which is why it must be a single controllable entity). Many microgrids do see an opportunity to aggregate flexibility within the microgrid and offer this to the TSO (and in some cases to the DSO) as an Ancillary Service, to create a revenue stream. But in that case the microgrid acts like a prosumer and the obligation for disturbance-neutrality remains with the DSO or TSO.

CSOs, Community Grid, and the Living Lab

MPOWER aims to be the first commercially licensed CSO in the world and has set an ambitious goal to achieve this within 5 years. Much applied research is needed before this, and to be continued after this. Some of the research questions to be answered are:

- ***So what does disturbance-neutrality on a logical connection mean?*** This philosophical question must be answered before CSOs can become a reality. The concept of logical connection is not new. It is similar to aggregators like VPPs or Retail Suppliers. The difference is that for aggregators, the relation between the resources that are 'on' that logical connection is relatively simple, namely aggregation (summation), while for a Community Grid it is the more complex disturbance-neutrality. For most disturbances this is relatively simple, e.g. phase imbalances can relatively easily be abstracted for a Community Grid as long as it is known what physical connections are on what physical phase (which requires system identification algorithms, or information from the DSO). But for others, specifically those that affect voltage, that relation will be more complex.
- Because CSOs guarantee disturbance-neutrality, it should be possible to apply a simplified procedure for grid connections, if they are part of a Community Grid. This entitlement is part

[7] https://www.nrel.gov/international/pdfs/5a_ton_reif15.pdf, page 5 or https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy%27s%20Microgrid%20Initiative.pdf page 84.

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of the CSO license. How far can this go, how much in terms of time and money does a simplified procedure save for the Community Grid, what about change procedures (e.g. prosumer disconnects from the Community Grid after the grid connection was approved through simplified procedure)?

- To be able to hold a CSO accountable for disturbance-neutrality, an essential part of the CSO license, it must be possible to monitor its performance. Monitoring means that disturbance-neutrality must be measured, which brings us back to the question: what exactly does disturbance-neutrality on logical connections mean? The DSO will play a key role in monitoring the performance of CSOs.
- Today's smart metering standards do not sufficiently support innovative concepts such as Community Grids. They are designed primarily to support Energy Markets, specifically Retail Suppliers and energy efficiency ESCOs. But they fall short in supporting local Energy or Flexibility Markets operated by actors other than the DSO, who often are the only authorised actor to communicate directly with the meter. For that reason, MPOWER is developing its own standard smart metering solution, but it is to be hoped that that could eventually be replaced by a standard smart metering solution that supports a much wider range of innovative grid-edge solutions, such as the CSO. So in order to get to that point, what changes would be required in the current standards for smart metering?
- Since CSOs autonomously provide disturbance-neutrality, and generally do that more economically than TSOs and DSOs, it should have a positive impact on the costs for the TSO and DSO to maintain disturbance-neutrality. These costs are covered by the regulated TuOS and DuOS tariffs, which are part of the retail tariff that consumers pay. Quantifiable savings by the CSO should result in a re-distribution of part of the TuOs and DuOs from prosumers, to CSOs. What are the methods by which this can be done transparently and justifiably? Initially, re-distribution could be based on expected/estimated savings, and partly paid by the PSO. This is similar to how energy efficiency is rewarded, with carbon credits for estimated efficiency rather than measured energy efficiency (energy efficiency is notoriously hard to accurately measure). But the expectation should be that once disturbance-neutrality can be measured, these savings can be more accurately quantified.
- Once several CSOs operate within the same area, there may be opportunities for CSOs to trade with each other, or indeed with the DSO. In a way this is like another level of a local Flexibility Market, but the main difference is that it is not a single buyer market. It could therefore be operated by a separate regulated party, not necessarily the DSO who instead could be one of the buyers in this market. Such a market could be used to get better physical disturbance-neutrality, effectively CSOs share their assets through this market, and work more closely together to achieve the common goal of physical disturbance-neutrality. Sometimes disturbance-neutrality may have to be relaxed for one CSO to solve a bigger local issue, and this needs to be accounted for in the market, e.g. in performance monitoring. It also needs to be carefully supervised by the DSO.
- In the more distant future, so called Utility microgrids may become a reality. These are microgrids that are part of the Distribution System and thus operated by the DSO (the Utility). By islanding, the local area could become more resilient for wider fault situations, but it also means that DSOs must balance supply and demand (although only when islanded), which today they do not do. This may be made easier by CSOs trading energy and flexibility with each other locally.

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- Finally, what is the role of the local authorities? Should Local Authorities have a stake in the local operation of Distribution Systems (in many countries they already do), and could the CSO maybe provide this, e.g. through more localised licensing of CSOs?

The first iteration of this research is already ongoing in the **cPAD** project (Community Grid Prototype and Demonstrator). The cPAD project is led by DIT and funded by the other partners: IERC, MPOWER, SDCC, Siemens, CRES (Community Renewable Energy Supplier, a commercial community focussed electricity supplier and aggregator, and constituent of the Tipperary Energy Agency), Systemlink and mSemicon. It will address technical, commercial and regulatory aspects of Community Grids, including a commercial franchise model for MPOWER as the first-ever-to-be CSO. The feasibility of Community Grids, and specifically local Flexibility and Energy Markets will be demonstrated in the Living Lab for stakeholders such as SEAI, CRU, ESB and Eirgrid as market operator. The Living Lab will thus be the "playground" to answer these research questions.

The Extension of the Living Lab, SEAI RD&D 2017 Call

Objectives

The Living Lab has since its inception managed to develop a wide feature set with limited resources, by strictly focussing on one specific new technology or infra-structure in each project. And although there was a well-defined vision from MEGA and SDCC how to develop distributed production, there was not yet a clear roadmap how that was to tie in with Smart Grids. This has resulted in an asset-rich Living Lab in terms of production assets and flexible assets, but otherwise the Living Lab is fragmented. Also, as the roadmap is becoming clearer, the importance of integration with Smart Homes and Smart Cities is becoming more apparent.

The 2017 SEAI RDD Project signals the start of a more integrated development of the Living Lab, to better facilitate the Energy Transition, including integration with Smart Homes and Smart City initiatives. At the same time, the MEGA/MPOWER concept of Community Grids and CSOs is now actively being developed to prototype stage (TRL 7), with help from IERC and industry partners, and this will need to be demonstrated in a suitable Living Lab.

To prepare for this, the project integrated various parts in the Living Lab with the enerXchange Prosumer Dashboard, integrated the solar PV powered microgrid in County Hall with the Community Grid Stabiliser, and added the possibility to have, in addition to on-line Prosumer Dashboard, a customised Public Dashboard for sites that can be visited by the general public. This was project managed as three strands in the project:

- Integrate the current LoRa monitoring solution with the existing Prosumer Dashboard.
- Add metering to the µDH (micro District Heating) system in Glenasmole, integrate with the Prosumer Dashboard, and add a Public Dashboard.
- Integrate the solar PV microgrid with CGS, such that 100% of the solar PV production is consumed on-site, in parallel with the Main Supply (the grid, or the backup diesel generator in case of grid-failure), with self-consumption monitored on the Prosumer Dashboard.

In the following chapters, the team is presented after which the three strands are described in more detail.

The Team

The team that implemented this project consisted of the following organisations:

1. MEGA. The mission of MEGA is to promote micro electricity generation as the primary solution to the long-term energy crisis and climate change issues through advocacy, communication, education and the removal of barriers through joint or co-operative action. MEGA provided Project Management and Technical Leadership for the project. The Project Manager is Rene Peeren MEngSc Beng. Rene has 30 years' experience in software

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development, first in telecommunications and later in Energy, specifically smart energy solutions. He was responsible for the development of Endeco's Demand Response system, which is now operating as DSU in the SEM, and their Frequency Response system, which is now operating in UK. He was pivotal in the development of the Community Grid concept and the CSO, and is now the Principal Investigator in the cPAD project.

2. MPOWER. MPOWER have been operating the Living Lab ever since its launch in 2012. They have directed the installation of the meters, the development of the enerXchange server prototype, and the micro District Heating system in Glenasmole.
3. Spriodcom Ltd. has in-depth technical knowledge and expertise in the Design and Integration of LoRa Communications systems. This includes full End-to-End systems from Nodes, e.g. Electric meters, through Gateways and the Cloud to the Application layer. In this Project, Spriodcom will be responsible mainly for LoRa communications connectivity to the Electric meters of the Prosumers along with Interfacing Data from the Electric Meters via the LoRa Gateways to the enerXchange Server and Prosumer Dashboard.
4. Freqcon GmbH from Germany has extensive experience in developing and manufacturing power converters and control systems for the renewable energy industry. The company was involved in the development of the first MW-scale battery storage system for the Chinese market and has developed a number of software- and hardware solutions for energy storage and grid stabilisation systems, including the Community Grid Stabiliser in the Living Lab.
5. mSemicon was established in 2001, in Dublin, and has decades of experience in the development of electronic products. The company specializes in many sectors, including industrial, medical, sport, lighting, and particularly HVAC (Heating, Ventilation and Air Conditioning). The company is particularly strong in real world applications where the scope of the engineering project extends past the mere development of a circuit board and its software, to the system of machines and processes in which the board operates. Many current products in development contain network connectivity elements to them, including RF (radio frequency, e.g. LoRa, Sigfox), which are common to the project at hand. They are also a partner in the cPAD project.

LoRa

For Smart Cities, and also for fast roll-out of enerXchange, a solution that can be deployed quicker and which is less intrusive to prosumers is important. LoRa is in that respect an interesting and very economical technology that allows for wide coverage with a single base-station. A separate LoRa network was already deployed for 13 prosumers in the Living Lab. These are connected to a LoRa network server (LoRa Collector). But the LoRa Collector was not connected to the enerXchange server, and therefore the data could not be accessed through the Prosumer Dashboard, only through the ThingSpeak Cloud platform that was used by the LoRa Collector. The only way for the Prosumer Dashboard to access meters was via fixed internet connections.

The task for this strand was to integrate the current LoRa monitoring solution with the existing Prosumer Dashboard in the enerXchange Server prototype.

The existing Prosumer Dashboard uses a data acquisition and web-based dashboard solution developed by Neodyne in a previous SEAI RD&D project. It uses Modbus TCP to collect meter data from MPOWER's electricity meters (PM 3112 and PM 2133), at 10 seconds intervals. One remote meter was connected for testing.

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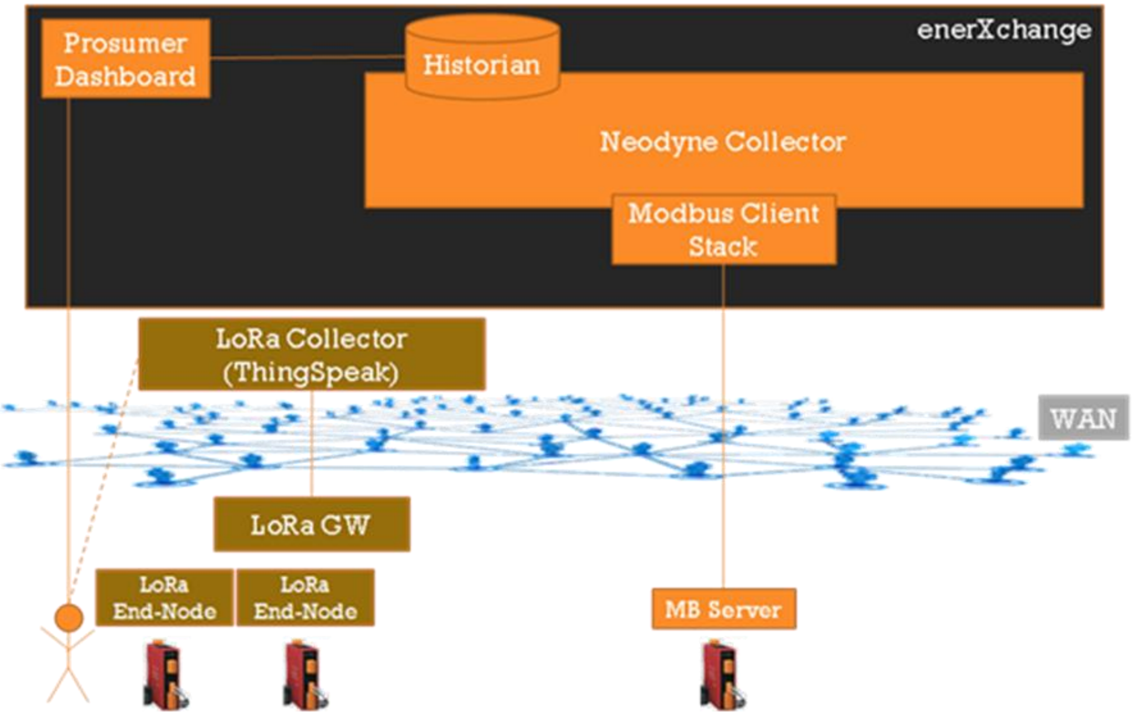

fig 5. LoRa Integration, Old Architecture

The Prosumer Dashboard was not planned to be updated in this project. Spriodcom therefore developed a LoRa to Modbus bridge function to connect the LoRa Network Server to the enerXchange Server. A separate Modbus TCP Server (MB Server) is instantiated for each meter for which data is collected via LoRa. Standard, off-the-shelf components were used, but some software development was needed.

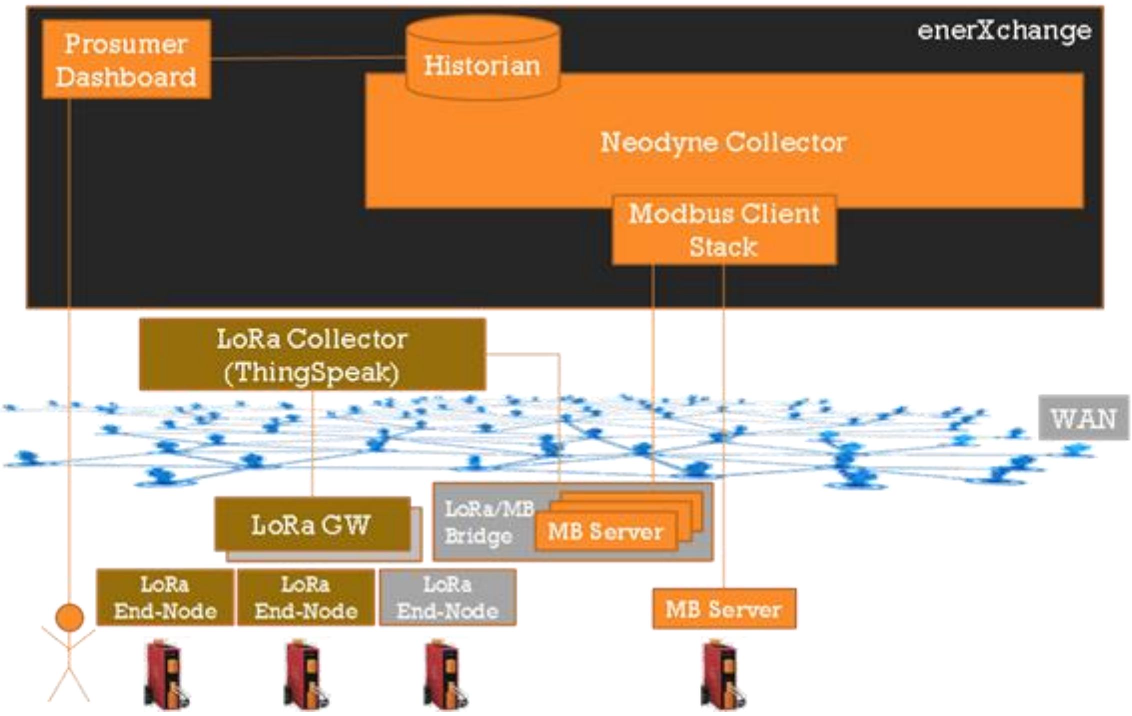

fig 6. LoRa integration, New Architecture with Modbus Server in LoRa Master

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MEGA

µDH system in Glenasmole/Bohernabreena

The CHP-powered µDH system was installed by MEGA/MPOWER. It serves the GAA club and 3 adjacent houses with prosumers.

The µDH system is hosted by the GAA club, who also supplies the gas for the CHP. The system has 3 circuits for supply of heat, and supplies electricity directly into the GAA (behind-the-meter). Currently it is not connected to enerXchange, in fact there is no access to any data. This limits the research potential of the system. Also, the GAA club cannot monitor the electricity produced (there is an MPOWER meter at the main incomer, but that only shows net positive demand), and crucially heat consumed on each prosumer circuit cannot be monitored either. As a result, the heat supplied could not be settled properly with the prosumers and the system was turned off after a successful test period pending the addition of appropriate metering and settlement systems.

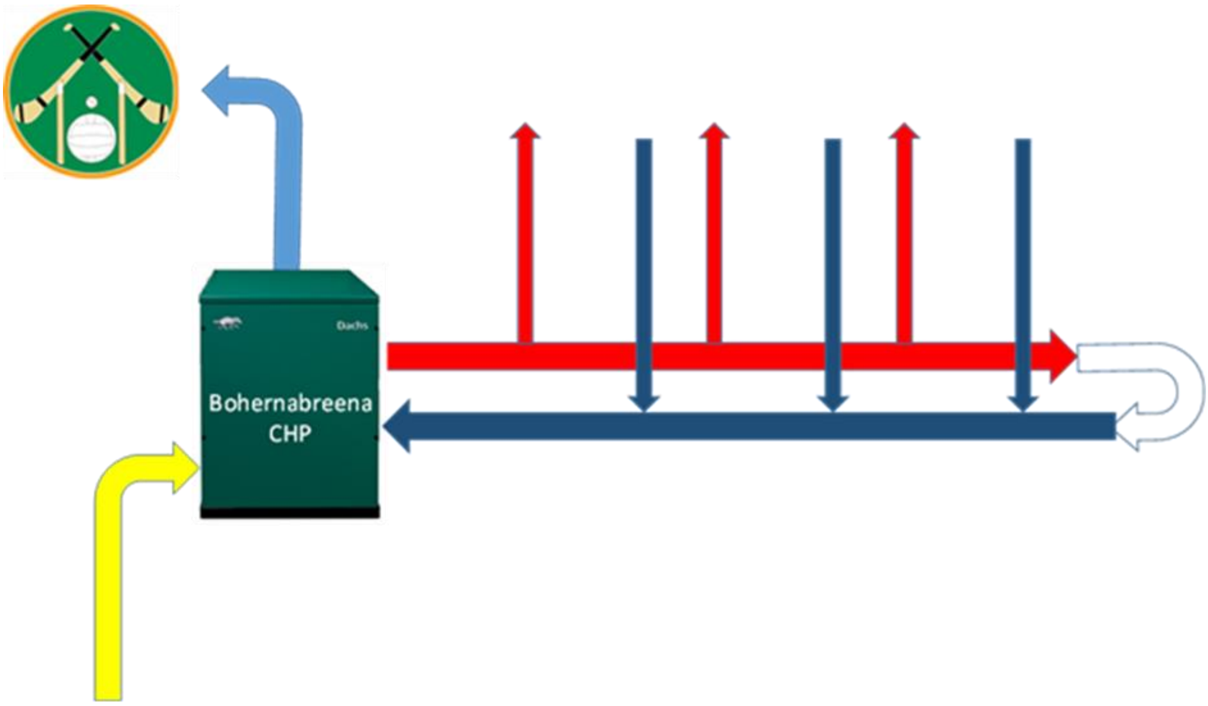

fig 7. µDH integration, Old Situation

To improve this, a total of 6 meters were deployed in the µDH to measure heat consumption for each of the three heat circuits, gas consumption of the CHP, total heat production and total electricity production. A solution was developed by mSemicon and Spriodcom to allow access from the Prosumer Dashboard via LoRa so that the data can be accessed by the Prosumers and the GAA club. Furthermore, a customised dashboard was installed in the GAA for public viewing, called the Public Dashboard, and a survey was conducted how heat can be delivered efficiently to the GAA.

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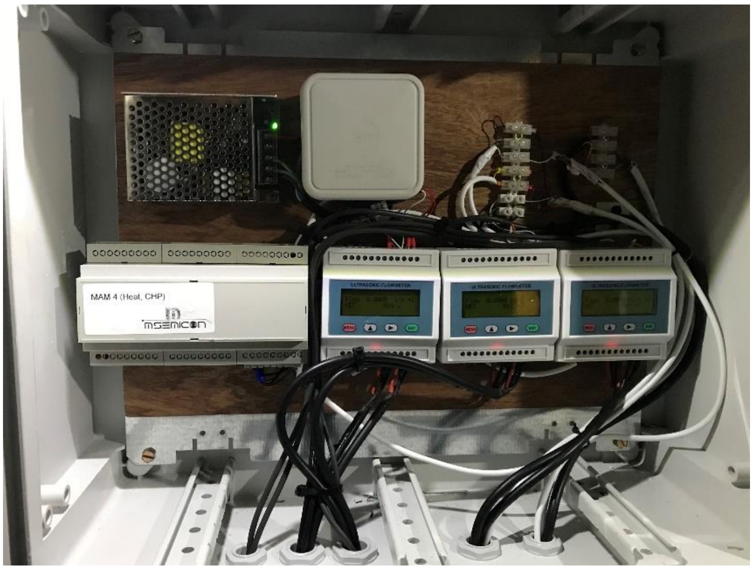
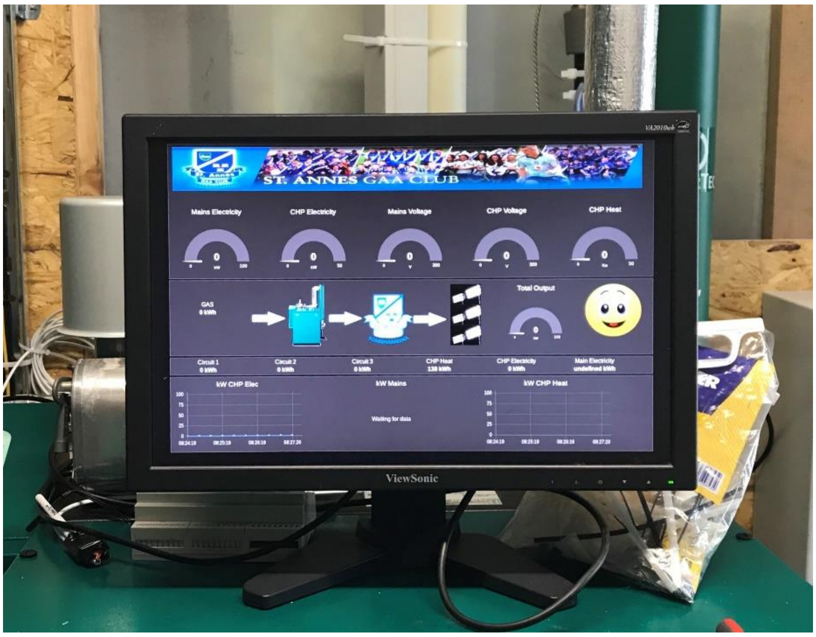


The core component was a Meter Adaptor Module (MAM), developed by mSemicon, which was fitted between each meter and the LoRa End-Node. It implements the following external interfaces:

- With the meter, for collection of meter data. This interface is meter specific. For the electricity meter (PM 2133) it is an RS 485 interface with Modbus RTU.
- With the LoRa End-Node, for offering the meter data to enerXchange. A Modbus RTU Slave in the MAM is connected to the existing Modbus RTU Master in the LoRa End-Node via an RS 485 interface.
- With a Pubic Dashboard anywhere on the GAA site, for continuous local visualisation of relevant data. The Public Dashboard can be placed anywhere on the GAA site. It collects data from one or more MAMs on the same site for display.



The Public Dashboard was found to be very useful in engaging the building occupants, in this case the GAA club. It allowed them to offer a niche service to visitors. Based on that positive experience, the intention is that similar Public Dashboards will be deployed in other sites in the Living Lab, re-using as much as possible of the MAM(s) and the data collection software in the Public Dashboard. It will become a permanent feature of the Living Lab.

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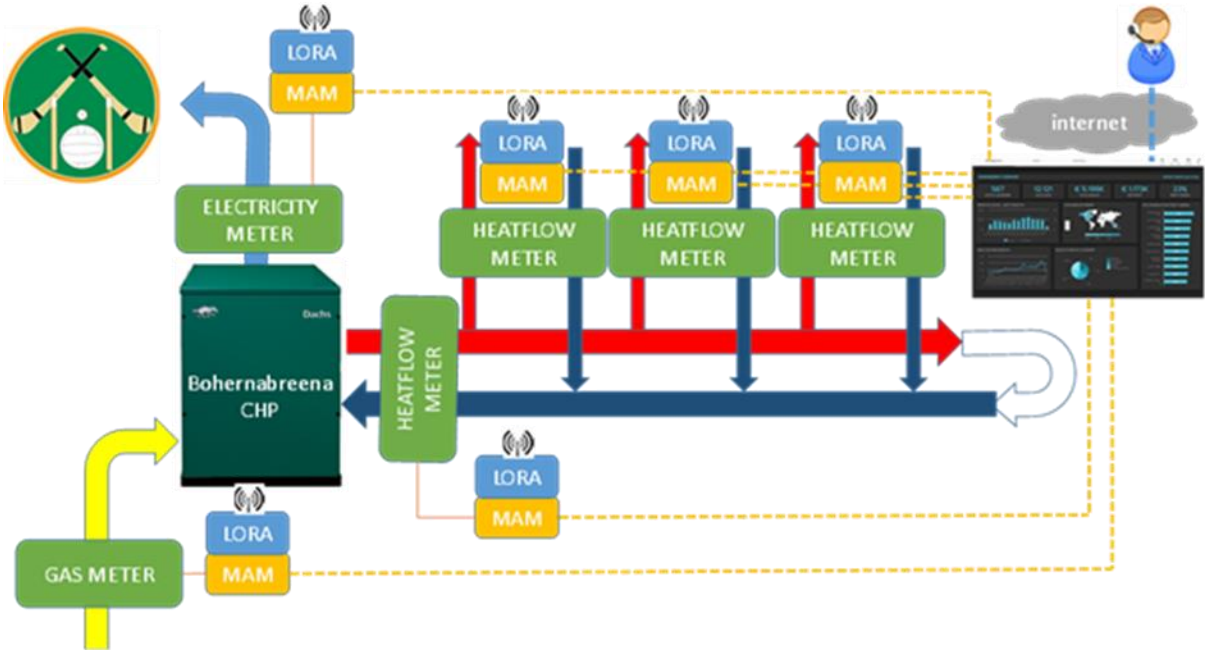

fig 8. µDH integration, Target Solution

Solar PV Microgrid

South Dublin County Hall has a standby diesel generator. It also has solar PV. Both can serve the same load, but the PV is not operational because no appropriate control strategy has been implemented to avoid spillage onto the grid. This was not helped by lack of documented directives from ESB regarding the protection that should apply to behind-the-meter generators of that size. A solution was deployed, called EMMA, but that solution was not approved by ESB-N. Some of the load is critical load for the county, most notably the traffic management network, so a solution based solely on e.g. G10 was undesirable as it will trip the load.
To make the PV available for research, and in the process produce savings for SDCC as part of their public obligation to save 30% by 2020, the solar PV microgrid was connected to the same grid connection as the CGS (the Battery Array), and the CGS was programmed as to avoid spillage onto the grid. Most of this work was software development by Freqcon, who also developed the current software. It ensures that all electricity produced by the solar PV is consumed locally, using the CGS, and allows performance of self-consumption to be monitored on the Prosumer Dashboard.

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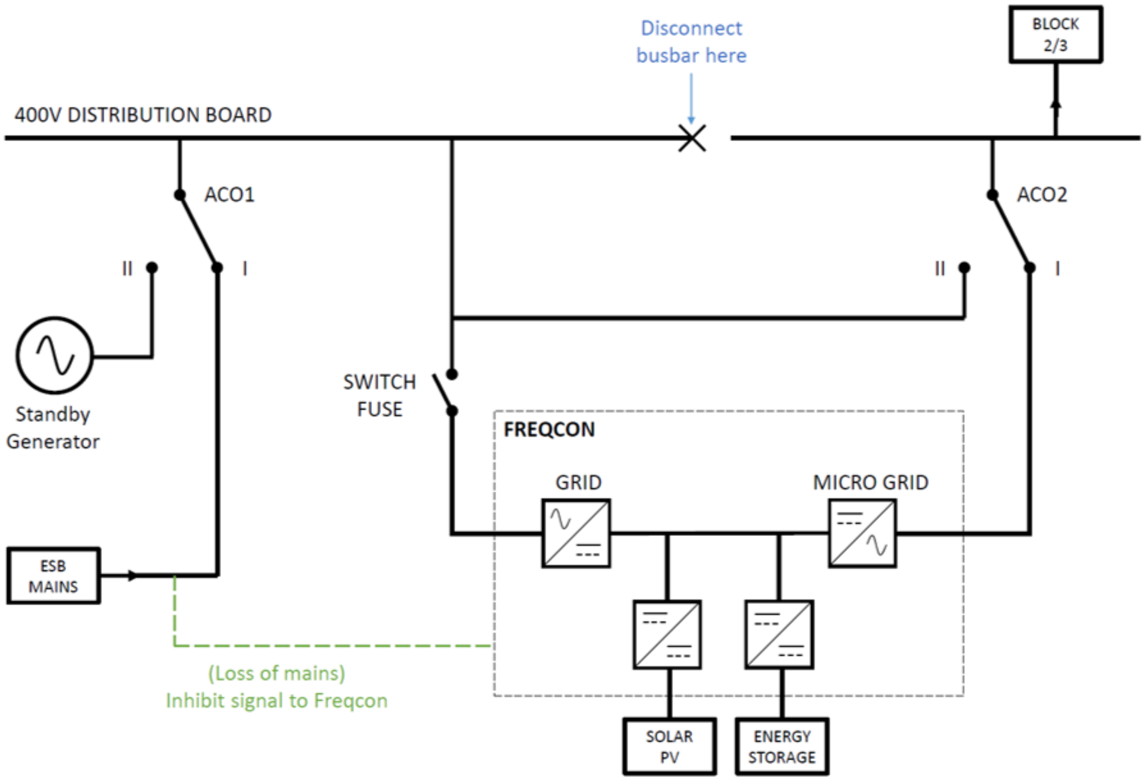

fig 9. PV-Battery integration, Target Architecture (Single Line Diagram)

Detailed specifications of the control regime:

- 'Main Supply' refers to grid and/or diesel generator.
- All electricity produced by the solar PV is only supplied to the Battery. The Battery may supply to the load.
- The Battery is automatically charged from the solar PV, and can be manually charged from the Main Supply.
- No solar electricity is ever fed back into the grid. This is implemented in the control logic, backed up by G10 protection (which should never have to trip to avoid export). The project was informed by ESB-N, late in the project and in response to earlier requests by the project, that G10 protection was required, but it should be noted that there is no formal documentation from ESB-N stating this.
- Production from the solar PV will only be curtailed during extreme long periods of low load, to avoid electricity being fed back into the grid. A formula is provided to estimate the yearly volume of PV production curtailed based on load profile, size of the battery and size of PV.
- An Operator Interface for the operator of the Living Lab is provided, through which the PV-Battery system can be managed, e.g.: start/stop operation, start/stop manual charging from solar or Main Supply, connect and disconnect battery from grid, change relevant set-points, and receive alarms. A manual is provided for the Operator Interface.
- Selected energy parameters are visualised on the Prosumer Dashboard in enerXchange. The data is offered to enerXchange using several Modbus TCP Servers, implemented in the control system and connected to the internet (i.e. not via LoRa).

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Key Findings and Future Development of the Living Lab

MPOWER's technology, called enerXchange, has a symbiotic relationship with the Living Lab: it enables much of the research in the Living Lab, while the Living Lab enables research crucial for the development of enerXchange.

For continued development of the Community Grid solution we will primarily use Horizon 2020 and Interreg as vehicles, focussing on integration within a wider context than energy, such as Smart Cities and Smart Buildings, as well as with other energy networks (gas, heat, transport). We participate, at co-ordination level, with the EU Commission JRP EUROMET, BATSTORM (EU Commission Battery Task Force) and JRC (Energy Policy Unit), in order to advance the Community Grid and CSO concept.

We will continue to develop the Living Lab as well. But now that the Community Grid solution is becoming clearer and more mature, the role of the Living Lab will evolve, becoming narrower focussed on supporting the continued development of Community Grids. The Living lab is destined to host the first commercial Community Grid, operated by the first even CSO. It will continue to host various innovative forms of flexibility and production technologies to underpin Community Grids. Also, a core feature remains the collection of large volumes of spatial data, which will be shared as much as possible with the wider research community.

With this more targeted focus, the mission statement of the Living Lab is:

The Living Lab will support the continued development of the Community Grid System, through demonstration of relevant technologies and business models, as well as sandboxed market and regulatory designs to inform policy makers and regulatory bodies.

This project has laid the foundation by integrating the various parts of the Living Lab with the, as yet, embryonic enerXchange system (the Prosumer Dashboard). With that in mind, key findings from this project are:

LoRa Wireless Network

Finding: ***LoRa suitable for near real-time delivery of live data for rapid analysis***

Details: Use of LoRa wireless technology proved to be both cost-effective and amenable to rapid deployment. A critical first task was to decide on the location of the Base Station (Access Point). Three critical requirements needed to be met:

- Proximity to Electricity Supply
- Sufficient RF signal coverage
- Adequate 3G/4G cellular signal strength for Backhaul.

Following a survey of the geographic area a site at Allagour (Glenasmole valley) was chosen which satisfied these requirements. All targeted Prosumer sites were reachable.

The LoRa End-nodes, by virtue of their extremely small footprint, were easily integrated into the Meter enclosures at the stakeholders` premises. This meant that no external devices were required resulting in near-zero disturbance during installation at the premises.

Micro District Heating

Finding: ***Live data is critically important when engaging with communities***

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The pre-existing micro district heating system did not provide access to live data. There was no metering, and as a result it was not possible to accurately settle the heat between the source of the heat (GAA, supplying the gas to the system), and the sinks of that heat (the three prosumers adjacent to the GAA building). Consequently, the micro district heating system was turned off. More importantly, the members of the GAA club i.e. the local community, started to lose faith in the project and largely disengaged with it and by extension, since the system is part of the Living Lab, with the Living Lab.
In this project we added metering, but found that the community was still reluctant to fully re-engage. It was not until we offered the Public Dashboard to them that the tide turned. A dashboard provides immediate feed-back of how the system acts, increasing confidence in the audience that the system operates to benefit them. Even just presenting an initial mock-up of the Public Dashboard, which we did early February, greatly improved their understanding and appreciation of the benefits of the system to the community. A picture can truly speak a thousand words. Now they are not only re-engaged, they are also re-energised for the next phase of the enerXchange project. A direct consequence of that success is that we are now discussing with the Glenasmole community, for which the GAA club is an important social hub, to be the demonstrator community in our enerXchange prototype project. We plan to invite SEAI, as a major stakeholder in renewable community energy, to the demonstration of that prototype, and hope that invitation will be accepted.
The Public Dashboard has demonstrated that presenting concepts through visualisations fed by live data that the audience can relate to, is a powerful tool in increasing the understanding of the audience, even of relatively complex concepts such as Community Grids. The intention is that similar Public Dashboards will be deployed in other sites in the Living Lab.

PV powered microgrid

Finding: ***Flexibility does facilitate the integration of more renewables***
Details: the PV panels on the roof of South Dublin County Hall were installed in a previous SEAI-supported project. It was installed on an existing connection to the Distribution System, which already had load on it, thereby creating a PV-powered, grid-connected microgrid. However, the panels could not be activated because it could not be guaranteed that it would not export on the 0 MEC grid connection, other than by G10 protection units that when activated would also interrupt critical load such as the Tallaght traffic light system.
That scenario is in fact very similar to power flow reversals that may occur in the Distribution System with local renewable production, a disturbance that when it occurs causes technical issues such as inaccurate readings, protections failures, even faults. This project offered an opportunity to demonstrate, in a safe, sandboxed environment (the microgrid) that this disturbance (power flow reversals) can be neutralised using flexibility, controlled independently from the solar PV (and therefore potentially owned by different actors). The Community Grid Stabiliser, which amongst others contains a hybrid battery array, is used as the flexible asset. It consumes (charges) all energy produced within the microgrid (in this case only from the solar PV), and produces (discharges) this energy when consumption is large enough. This control regime has allowed the PV panels to become operational, by ensuring that nothing is ever spilled onto the grid. As long as the battery is large enough, more production from any energy source can be added without causing power flow reversals, thus demonstrating the ability to support more local renewable production.
This is especially relevant in the context of Net Zero Energy Buildings. NZEB buildings require electricity production that is located in, or nearby the building. Without neutralising disturbances such as power flow reversals, a high take-up of NZEB, as surely is the expected outcome of the

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building regulations, will most certainly de-stabilise the grid. This side-effect from the NZEB regulations is often forgotten, but if not addressed will severely constrain the wide spread implementation of NZEB buildings. We would welcome the opportunity to discuss this in more detail with SEAI.

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