SEAI Research, Development and Demonstration Funding Programme 2021

Sustainability Dingle

Deliverable - Final Management Report

Deliverable number – WP1-D2

Date: July 2024

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This report has been funded by the Sustainable Energy Authority of Ireland under the SEAI Research, Development & Demonstration Funding Programme 2021 Grant number 21/RDD/763

Date:	**July 2024**
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Workpackage:	**WP1 – D2**
Nature:	**R = Report**
Version:	**V1.0**

Disclaimer: All information provided reflects the current status of the planning of the Sustainability Dingle project and may be subject to change over the duration of the operation.

Contents

Glossary of Terms

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SEAI	Sustainable Energy Authority of Ireland
SETU	South East Technological University
UnG	Údarás na Gaeltachta
P2P	Peer to Peer
EC	Energy Community
REC	Renewable Energy Community
CEC	Citizen Energy Community
kWh	Kilowatt-hours
PV	Photovoltaic
DSO	Distribution System Operator
TSO	Transmission System Operator
RED	Renewable Energy Directive
IEMD	Internal Electricity Market Directive
RSC’s	Renewable Self-Consumers
SRESS	Small-Scale Renewable Electricity Support Scheme
MEC	Maximum Export Capacity
MIC	Maximum Import Capacity
SEC	Sustainable Energy Community
EMP	Energy Master Plan
DUoS	Distribution Use of System
CREST	Centre for Renewable Energy Systems Technology
ISSDA	Irish Social Science Data Archive
CSR	Corporate and Social Responsibility
SLR	Special Load Ratings
EV’s	Electric Vehicles
HP’s	Heat Pumps

1 Introduction

The Sustainability Dingle project was funded through the Sustainable Energy Authority of Ireland's (SEAI) National Energy Research Development and Demonstration (RD&D) Funding Programme 2021. It ran from March 2022 to May 2024. It was led by the Walton Institute from the South East Technological University (SETU) with Údarás na Gaeltachta (UnG) as partners. Mol Teic t/a Dingle Creativity and Innovation Hub and Corca Dhuibhne Community Energy served as collaborators on the project.

The Sustainability Dingle project has delivered a Sustainability model which can maximise a regions balance of its load with locally integrated Renewable Energy technology within Energy Communities (EC's). Ireland has significant potential to engage the energy citizen as central tenants of the Clean Energy Transition. New EU Directives have been implemented which place the energy citizen at the centre of this transition. Ireland is in the process of transposing these Directives into law and an opportunity exists to implement mechanisms which will have a lasting impact on our Sustainability as a nation. Key to these developments is the creation of Energy Communities where Renewable Energy Technologies can be implemented locally such that they can be sustainably balanced using mechanisms such as Peer to Peer (P2P) energy trading, Demand Side Management, Load Shifting and Battery Storage.

EC's are now enshrined in EU law as a central pillar in delivering the energy transition which includes non-energy professionals in the process. Putting communities at the centre of the transition involves citizens in the development, ownership and ongoing reward that EC's can offer. This improves project acceptance and sense of self determination and citizens become involved and supportive of its goals. Also, integrating local renewable energy in a balanced manner allows communities to become sustainable. By giving citizens, the intelligence and technology to take ownership of their energy profiles, they will control their interactions with the market and become prosumers. Local energy makes electricity less expensive and renewable energy more profitable and supports new and better mechanisms for return-on-investment where mechanisms such as peak shaving can be enabled. By EC's generating more of their own energy locally in a sustainable way provides many benefits to the wider grid. It gives better utilisation of existing network capacity in a balanced manner. As generation is local, it reduces system losses in both the transmission and distribution systems. This will also reduce future grid reinforcement as the region becomes more sustainable. Social values are also enhanced in communities providing an alternative model for the governance of energy resources with financial rewards and increased local investment, positively impacting on job and employment opportunities.

The Sustainability Dingle project is a direct follow on from previous work completed during the Interreg Northwest Europe RegEnergy project, which developed a software platform to manage and optimise the flow of energy within 2 Pilot EC's in the Dingle area – one in an office block, the other in an Industrial Park. The loads in these EC's were analysed and aggregated and renewable energy and smart grid systems integrated to maximise the self-sustainability of these 2 EC's. In this project, we have acquired data for the wider Dingle area from various sources and built models to form a picture on the level of balancing that can be achieved using Energy Community concepts as these micro-EC's are rolled out geographically and expanded along the network across the region.

This Final Project Report will cover all of the aspects of an EC and how the data to feed the models were acquired, analysed and mined to provide an accurate picture of the load profiles on the network and its operation. We will outline how the integration of Renewable Energy systems and how they are modelled can balance these EC's and how battery systems can contribute to the process. However, for these EC's to prosper, mechanisms from the transposition of the new EU Directives such as P2P energy sharing are essential and the legislative and regulatory processes to implement them must be prioritised.

As the Clean Energy Transition progresses, other energy demands outside of electricity such as Heat and Transport must also be sustainable, and we assess how EC's can play a major role as these sectors are electrified. We also assess the effect on the network of significantly increasing the level of renewables, batteries and the electrification of heat and transport on aspects such as voltage change and line loading. Finally, we will outline the software platform which facilitates the user to visualise the network in a particular area and create EC's along the grid. The system then designs the optimum level of renewables and batteries to maximise its sustainability.

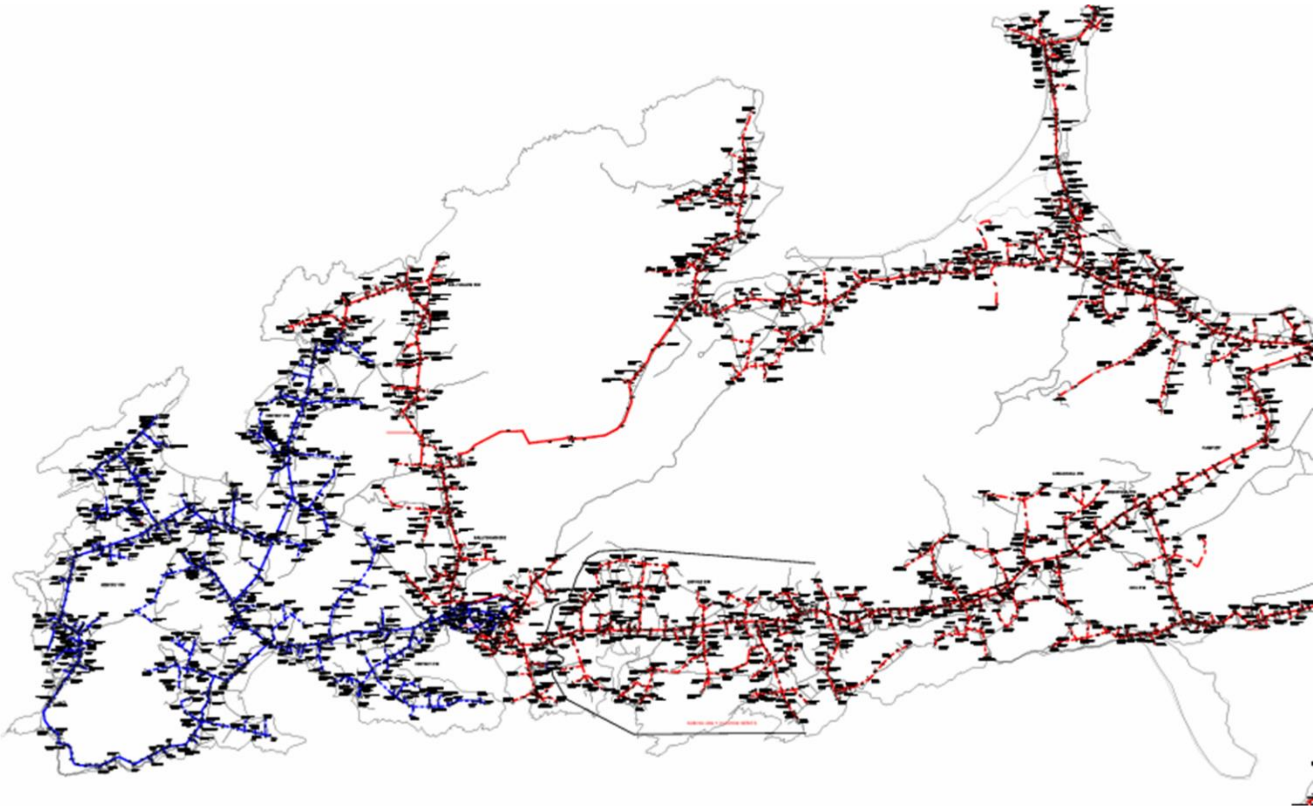
The project team, partners and collaborators were able to engage with a wide network of industry and local stakeholders and access a myriad of data and research from previous projects. This proved essential to the objectives of the project being achieved and contributed considerably to the results. All data sources are included in the Reference section at the end.

2 Energy Markets – Background

Electricity networks were designed and operated to be unidirectional with energy being generated at large fossil fuel fired power plants and distributed out along a network to end users. For the Clean Energy Transition, we must integrate renewable energy sources, which are intermittent and variable by their nature. To overcome this aspect, some of these renewable assets must be incorporated into the network in a distributed fashion, at or close to the site of consumption. EC's can be the driver to enable the mechanisms required to achieve this and using smart grid techniques can facilitate the paradigm shift that is required to transform the current unidirectional system to an intelligent network where supply and demand can be balanced with distributed and renewable sources of energy.

Energy Prediction and Optimisation is the link to give the intelligence and control to allow end users become prosumers and facilitate them to be key players to drive this new paradigm shift. This can facilitate end users to pool their resources in Energy Communities and participate in the market and potentially become price makers as opposed to price takers. This citizen engagement will embed these EC concepts within communities and ensure they become common place and will endure into the future.

For EC's to propagate, they must evolve within the current network systems. ESB Networks are the Irish Distribution System Operator (DSO). They, along with Eirgrid, who are the Transmission System Operator (TSO), are responsible for the development and operation of the national electricity network. The large power stations traditionally distribute electricity along the grid through a series of 400kV, 220kV and 110kV networks, operated by the TSO. As the network is transformed down to the DSO level at 38kV substations where 20kV and 10kV feeders distribute the electricity to local transformers feeding Residential, Commercial and Industrial clients. This spiders web of network can be seen in the Dingle network below. The Tralee 110kV substation feeds the Dingle 38kV substation which then has 4 feeders distributing electricity along 10 or 20kV lines to each node on the peninsula.



ESB Networks operate the system from 38kV down to end user level. Security of Supply is their primary concern and always maintaining a consistent supply. As load profiles change radically in some locations due to seasonality and other issues, there is a large Factor of Safety built into the network. This ensures a high degree of resiliency ensuring capacity can meet requirements. However, this leads to a low asset efficiency use. For the Clean Energy Transition, we need to integrate renewables at a distributed level. However, the DSO must assess the capacity of the network to integrate these renewable assets on a 'worst case scenario' – that is, does capacity exist on the sunniest/windiest day when the local load demand is at its lowest. In many cases, renewable projects are failing due to this strategy. EC's, where renewables are intelligently controlled and balanced locally, can play a significant role in removing fossil fuel generation and using the network assets to their limits more regularly. The EU have recognised that they must engage the Energy Citizen more centrally in the Energy transition and unlock the potential of EC's. The next section outlines the Directives they have put in place to enable this.

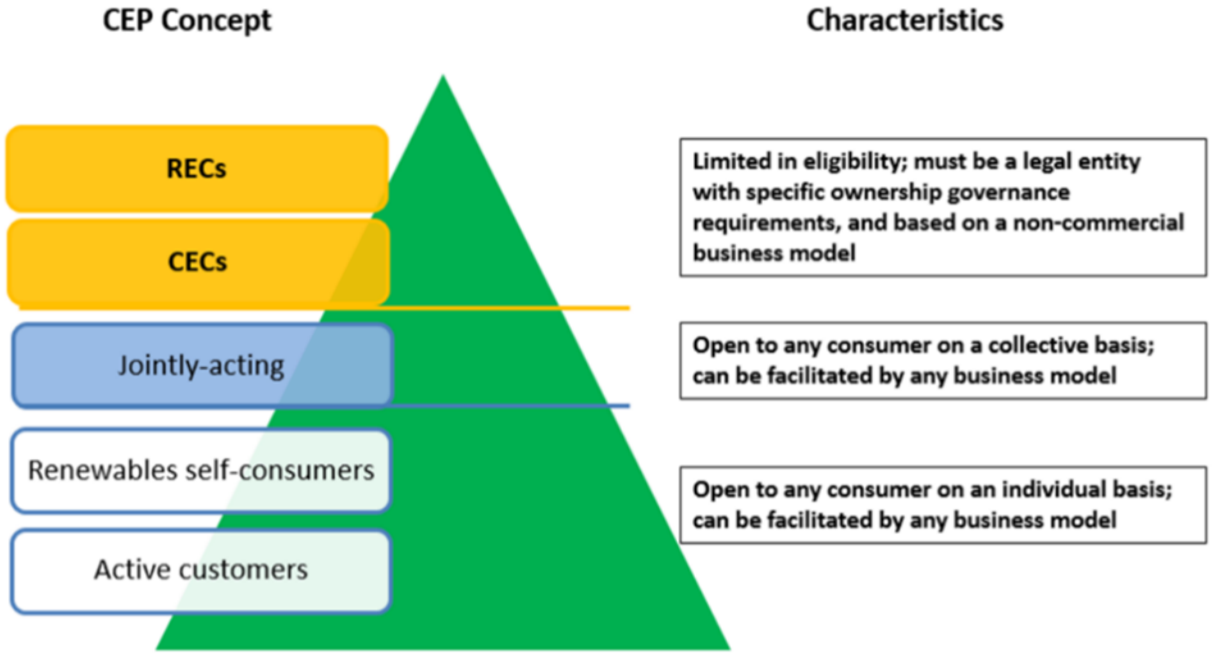
3 Regulation – EU Directives

With the Clean Energy Package, the EU have introduced provisions on the energy market design and frameworks for new energy initiatives. Specifically, the Renewable Energy Directive (REDII) and the Internal Electricity Market Directive (IEMD) provide basic definitions and requirements for the activities of individual and collective self-consumption as well as for energy communities. Renewable Energy Communities (REC’s) and Citizen Energy Communities (CEC’s), allow citizens to collectively organise their participation in the energy system. Each EU jurisdiction must transpose these new laws into their national regulation, but each can implement the rules in a way that suits their respective energy markets. This is leading to a haphazard implementation at variable rates with different mechanisms and interpretations under review. Mechanisms such as P2P trading are a radical change to current conventional markets but have the potential to make a significant and lasting impact on the clean energy transition. With this significant challenge comes opportunity. REC’s is the focus of this project, where new concepts such as P2P trading can open the way for new types of energy initiatives aimed at the empowerment of smaller actors in the energy market as well as an increase in decentralised renewable energy production and consumption, known as prosumers. The mandatory transposition into national law provides significant room for specific provisions.

Simple self-consumption is not specifically addressed in the Directives as it is realised that individuals acting on their own and sporadically spilling energy on to the grid has limited advantages to the local or national network. Where citizens are actively engaged in the market as prosumers and are organised in Energy Communities the rewards to all parties are significant.

The three main concepts addressed in the Directives are Renewable Self-Consumers (RSC’s) which may be Jointly Acting (JARSC’s), REC’s and CEC’s. There are both distinctions and similarities between the concepts to suit various scenarios. A major characteristic of RSC schemes is that they constitute a specific activity while not explicitly focusing on the organisational format. In contrast, energy communities focus much more on organisational and market aspects. Nevertheless, activities such as energy generation, distribution, supply, and consumption are specifically included as possible activities in the energy community definitions. Consequently, RSC’s may well occur as a specific activity in the context of an energy community.

JARSC’s are defined as a group of at least two cooperating RSC’s who are located in the same building or multi-apartment block. CECs and RECs have similar objectives in that each require a legal entity as a community umbrella, must be voluntary and open, should be primarily value driven rather than focusing on financial profits, require a specific governance and act collectively. CECs however have no geographic limitation, are based on electricity only and are technology neutral. RECs on the other hand have a proximity requirement, limited membership (shareholders or members do not include large companies) and are open to all sources of renewable energy (e.g. heat), but renewable energy only. The major purpose of the enabling frameworks is to promote the development and growth of RECs as a way to expand the share of renewable energy at national level while for CEC's it's to create a level playing field.



The discussion and first implementation of collective self-consumption schemes – where energy can be generated and shared within groups – is ongoing in most EU Member States who are introducing a regulatory framework to support it. As the energy sharing principle is central to realising the advantages EC's can bring, we are focusing on REC's where the proximity clause ensures the sharing is physical rather than virtual. The major purpose of the enabling frameworks is to promote the development and growth of RECs as a way to expand the share of renewable energy at national level.

The key to all concepts is the introduction of mechanisms that facilitate prosumers to act collectively and take control of their energy profiles. The concepts enable prosumers to generate, store, sell and share energy between themselves within a group. The concept of energy sharing has the potential to be the largest game changer in this transition. P2P energy trading is defined by the REDII as "the sale of renewable energy between market participants" by specific means including "the automated execution and settlement of the transaction". This may occur "either directly between market participants or indirectly through a certified third-party market participant, such as an aggregator". P2P trading has the potential to enable communities to act together in a collective way such that locally integrated renewable energy can balance the aggregated load of the group. P2P platforms are emerging using distributed ledger technology such as blockchain where energy surplus can be exchanged with their members neighbours and also energy provision/matching, where prosumers can directly choose local renewable generation.

4 Energy Communities

Although the EU Directives outlined above have been passed for some time, Ireland is still in the consultation phase of transposing these into national law. Government bodies such as the Regulator (CRU) and the Department (DECC) have issued various consultations around Active Consumers which explores terms and other concepts around new energy activities such as aggregation, energy storage, demand response, flexibility, and energy sharing with interested stakeholders. There have been significant information gathering exercises through Calls for Evidence and Roadmap plans - however, there has been little progress in their implementation. Some aspects on the structures of EC's are under consideration. These will be required as elements of an EC moving forward and may be 'mini steps' in a future, fully fledged EC. These include - Small-Scale Renewable Electricity Support Scheme (SRESS), the Proximity Clause of the Directive, Private Wires & Networks and the Installed Capacity Cap of renewable energy projects.

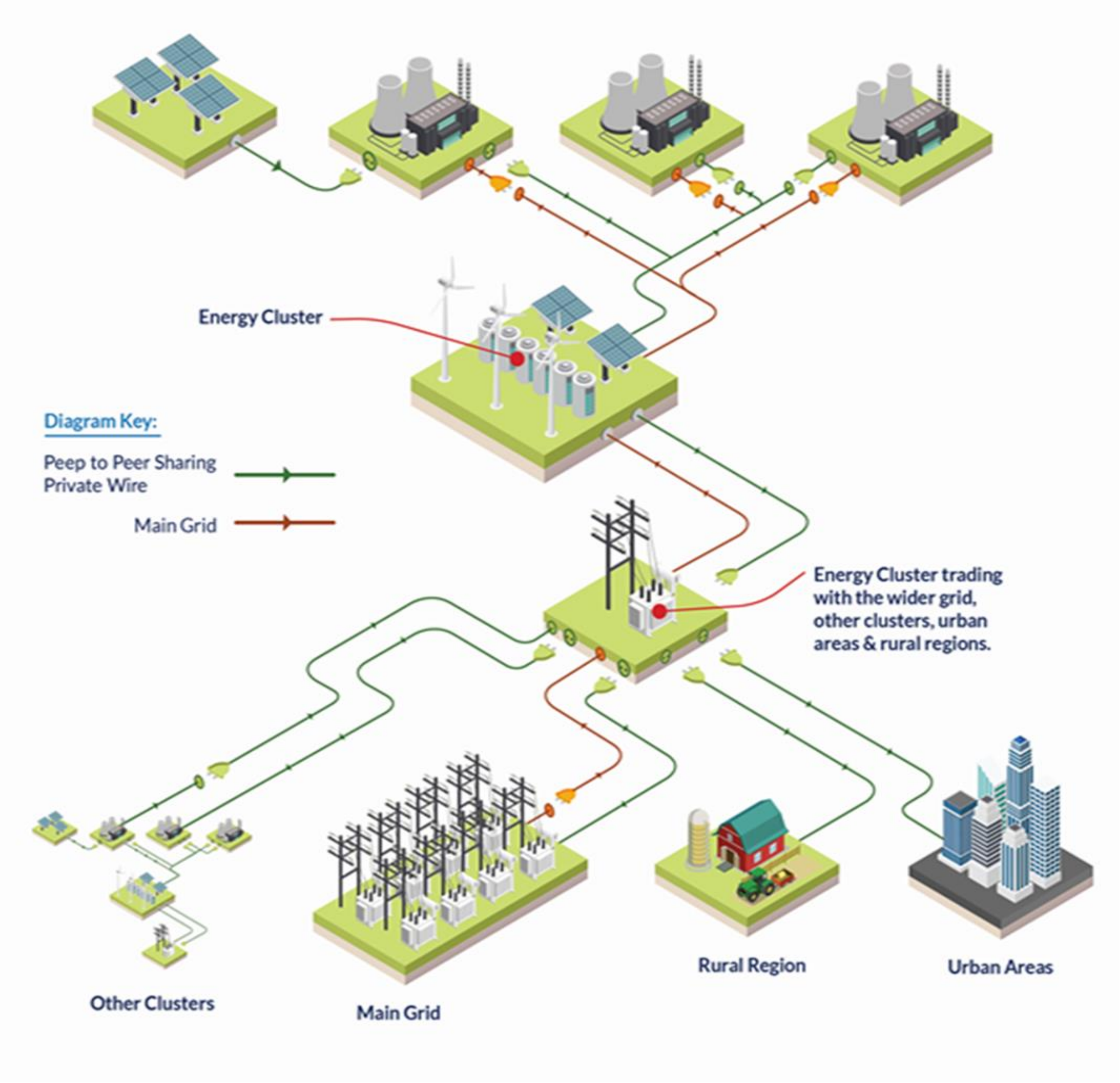
There are many examples across the EU where governments have transposed the Directives into their national laws and EC's are propagating accordingly. Portugal, France, Italy, Spain and Austria in particular have implemented mechanisms facilitating P2P energy trading and RSC's within EC's with rules around proximity, voltage levels, legal structures, grid fees and tariffs. Accordingly, innovative companies are developing technologies to service the market with management control systems such as Greenvolt and Cleanwatts (Portugal), ENTRNCE (The Netherlands) and Hive Power (Switzerland). There are many benefits that these EC's are providing to the local community and also to the wider grid, as follows.

- Puts Communities at centre of energy transition – improves project acceptance
- Integrate Local Renewable Energy in a balanced manner
- Provides a Business Model and facilitates capital mobilisation
- Facilitates Aggregation & Flexibility in the Market
- Reduces System Losses (Local Trading)
- Reduces Future Grid Reinforcement
- Better utilisation of existing network capacity

As Ireland must transpose the EU Directives into law, we can take the learnings of our peers across the EU and assess how EC's can play a role in sustainably balancing our grid. The Dingle peninsula was chosen for this project for a number of reasons. Primarily, the South East Technological University have completed a project called RegEnergy in conjunction with Údarás na Gaeltachta whereby a software platform was developed to manage and control the energy flows of an EC and give its members the technology and control to integrate renewable energy for themselves. There were 2 trial sites belonging to UnG in Dingle – one, an office block with approx. 10 separate offices within it and secondly, an industrial park with approx. 15 factories of various sizes. RegEnergy showed that EC's can integrate significant renewable energy and maximise their self-sustainability. The goal of the Sustainability Dingle project is to assess models whereby this strategy can be rolled out further beyond the trial sites to a regional level. Also, as the Dingle area has been used recently by ESB and others for Smart Grid trials, there was a body of work completed which could feed into our analysis.

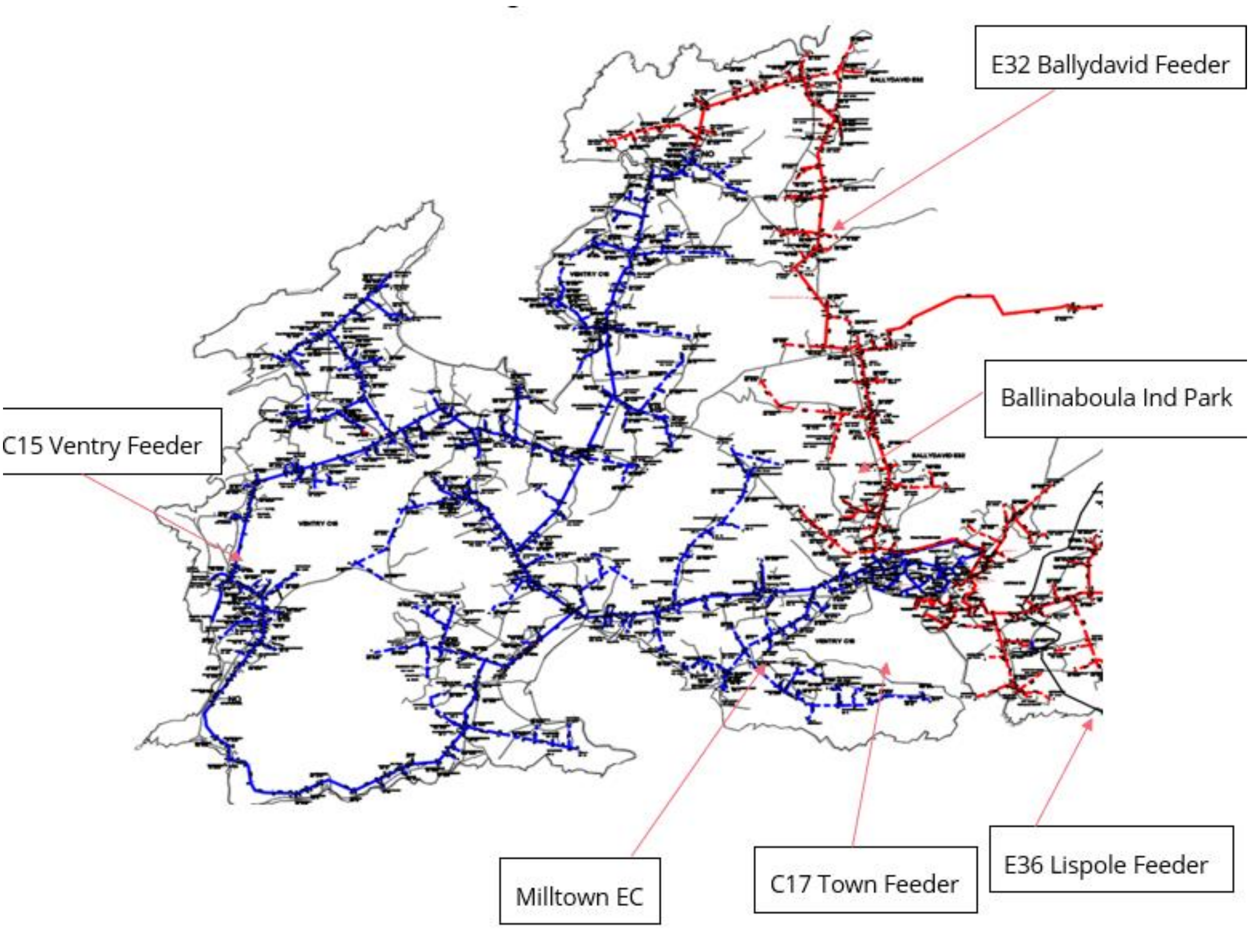
The RegEnergy project integrated smart metering systems into all of the offices in UnG's office block in Milltown and also the Dingle Distillery plant which is adjacent as well as 6 of the larger factories in the Ballinaboula Industrial Park. This facilitated the acquisition of granular data over a significant period such that SETU's prediction algorithms could build accurate models of their likely loads across all seasons. The map below shows the location of the 2 trial sites to the west and northwest of Dingle town.

RegEnergy demonstrated how the aggregate of offices or factories can group together and enable the integration of renewable energy and smart grid technologies to maximise their self-sustainability once mechanisms such as P2P trading are enabled. The graphic below shows how this concept can be rolled out geographically along the network using the 2 micro-EC's above as a base. These clusters can sustainably balance themselves but also trade with the wider network, spilling energy to them at times of over production and importing from them and/or the grid when demand outstrips local supply. The level of spill an EC can export to the grid is determined by the capacity of the local network and is known as its Maximum Export Capacity (MEC). This is the guideline used when integrating any generation capacity with the grid. However, as the goal of the EC will be to consume as much of its own generation as possible, the MEC of the cluster can be far less than the combined generation capacity of all its assets. In reality, even if the MEC of the EC is set at zero, the cluster could still integrate a large amount of renewables for its own consumption. A major element of an EC is the intelligent control systems which use Prediction and Optimisation technologies to match supply and demand at all times. These smart grid techniques, when allied with EC concepts, can facilitate the integration of large amounts of distributed renewable energy technologies bringing benefits to both the community and the wider grid.



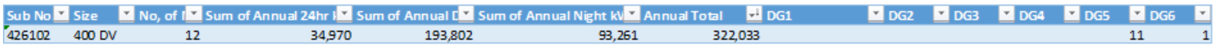
5 Dingle Network

The graphic below shows where the 2 micro-EC's of Milltown and Ballinaboula are on the regions Network map. To expand these EC's out, we follow the network grid as it brings electricity from the Dingle 38kV substation out to the region via 4 off 10/20kV feeders - E32 Ballydavid Feeder, C15 Ventry Feeder, C17 Town Feeder and E36 Lispole Feeder. The Ballinaboula EC is located on the E32 feeder while the Milltown EC is on the C15 feeder as shown. ESBN furnished the team with data outlining the details of each feeder and the type of meters (residential, industrial, etc) they feed through various transformers and their load profiles across the year. From the RegEnergy project, we had ample Commercial and Industrial data and as we will see in the next section, we identified accurate models to profile residential properties. With this data, the team were able to model accurate load profiles for each transformer on the network. This can then be aggregated up to model hourly energy flows for each feeder and consequently, the entire Dingle substation feeding the peninsula. As ESBN have granular hourly data at feeder and substation level, our models can be verified against this live data.



The team secured the locational detail of each transformer which enabled us to geographically plot the network on a regional basis. This is displayed in the software platform such that EC's can be developed at any point in the network and through the relational tree structure, neighbouring areas can be added which mimics the actual power flow of the network.

To conform with the technical requirements of the EU Directives and for mechanisms such as P2P energy trading, members of an EC must be geographically close to each other and behind the same transformer group such that if one member spills energy another can directly consume it. Therefore, to achieve the objectives of the project, detailed data of the local grid is essential. ESBN store their network data in a certain manner which outlines the number of customers and their type. This allows us to match the types of customers behind individual transformers. This data is critical so as the team can build typical energy profiles for the customer groups where smart metering systems are not in place. A small, redacted snapshot is included below.



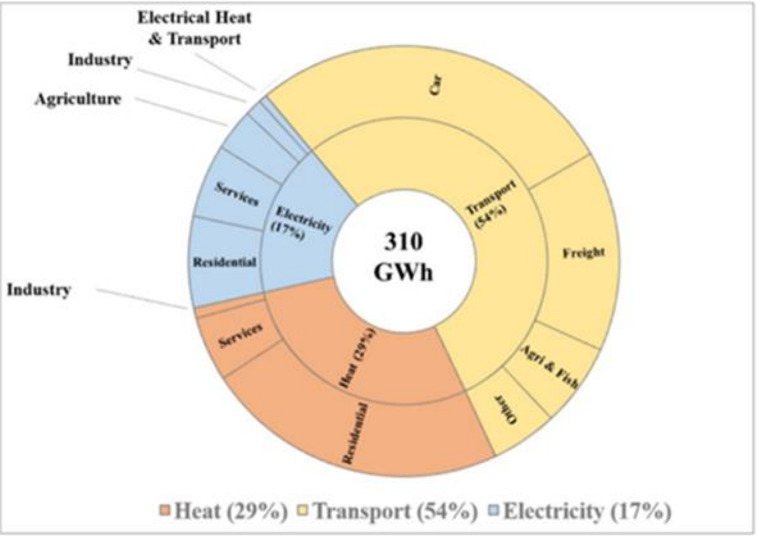
Sub No	Size	No, of I	Sum of Annual 24hr k	Sum of Annual D	Sum of Annual Night kV	Annual Total	DG1	DG2	DG3	DG4	DG5	DG6
426102	400 DV	12	34,970	193,802	93,261	322,033					11	1

Therefore, from the Ballinaboula EC perspective, we can now derive what types of loads exist for all the properties behind the transformers associated with the area and how they are all interconnected. This data allows us to build an annual profile of the energy usage on each feeder over a year. ESBN monitor the energy flow through each feeder line and record it on a half hourly basis. This is important, as when we design a Sustainability model with renewable energy, we must balance supply and demand across all hours of the year. The project team used modelling techniques to build hourly profiles over a year for the various load types from ESBN's 'Number of Customers' data for each transformer and aggregating it for all the transformers on that feeder. This can then be stochastically fitted to the profile for that feeder. Other publicly available network data include capacity heat maps and seasonal load ratings which allow us to verify the modelling profiles we generate.

6 Load Data & Models

In this section, we review the available load data for the region and how it is assessed and formatted to feed the Sustainability models required. Where local data is not available, we outline the techniques and models used to generate it and how the results were verified for the local region.

Peninsula Data – The Dingle Creativity and Innovation Hub are a collaborator on the project and have set up the Dingle Sustainable Energy Community (SEC) encouraging and supporting the involvement of communities in the transition to a low carbon future. A vital first step in the development of an SEC is to understand the community's current energy consumption, so the Dingle SEC commissioned the production of an Energy Master Plan (EMP) for the Peninsula. This document provides a baseline highlighting the relevant findings on the community's current energy demand, as well as the options available for reducing energy usage and switching to renewable energy sources. The energy usage across the Dingle Peninsula differs significantly to the national pattern for several reasons. Firstly, the rural and isolated nature of the area contributes to higher than average residential and transport demand. Secondly, the economic activity of the region is highly dependent on tourism, farming and fishing.



The Dingle Peninsula's energy use by mode in 2016

As highlighted in the graphic above, the key areas of concern on the Dingle Peninsula are private car travel and residential heating. This is primarily due to the Dingle Peninsula's geographical location as an isolated and sparsely populated rural area. Kerry is Ireland's fourth least densely populated county at 30.7 people/km2, while the Dingle Peninsula is even lower, at 21.5 people/km2. This is significantly lower than the national average of 70 people/km2. As a result, car ownership on the Dingle Peninsula is significantly above the national average at 547 cars / 1,000 people compared to 428 cars / 1,000 people, a difference of almost 28%. Heating also presents a challenge, with the area currently heavily reliant on the import of oil with LPG (liquid petroleum gas) and kerosene boilers representing 71% of central heating systems compared to 41% nationally. Likewise, solid fuel use is higher than average, with 17% of houses relying on coal, peat and wood compared to 6% nationally. In addition, given the rural nature of Kerry, the percentage of one-off houses is above the national average at 75% compared to 71%.

Although electricity is the smallest energy mode in the peninsula, it is the obvious place to start in decarbonising the sector due to the availability of technology such as renewables to replace fossil fuels. Section 10 below discusses transport and heat and how these sectors can follow electricity as they are electrified.

From Section 5 above, we were able to build a database of the type and location of every meter on the peninsula. The meter types indicate whether they are households, commercial or industry and what size they may be. As Dingle is a rural area, the number of residential premises far outweigh industrial. From the EMP, electricity spend per annum is broken down across residential, agricultural, industrial, services and public. ESBN data is broken down by type of meter (DG) which allows us to identify which sector it belongs to. As can be seen from the table below, residential (which includes holiday homes) is the most significant, followed by services (which includes commercial premises such as shops, hotels and pubs). The team have accurate granular data for industrial premises, but it is essential to secure sectoral data to represent the sections below.

Sector	Value €	Percentage
Industrial	186,177	2
Agriculture	306,000	3.3
Residential	6,160,556	67.3
Services/Commercial	2,041,668	22.3
Public	458,796	5

ESBN applies charges to customers based on their size via DUoS costs. DUoS stands for Distribution Use of System and the amount of DUoS that ESB Networks charges for use of the Electricity Distribution System for each customer depends on which DUoS Group a customer is classified as, which can be based on several factors including the voltage a premises is connected at, the type of meter installed, or if electricity is exported. From a Dingle perspective, the following are the groups of relevance.

DUoS Group

DG1 Urban Domestic Customers – Residential/Agriculture

DG2 Rural Domestic Customers – Residential/Agriculture

DG3 Unmetered Public Lighting - Public

DG5 Low Voltage Non-Domestic Non-MD Customers – Commercial/Small Industrial

DG6 Low Voltage Non-Domestic MD Customers – Large Industrial

In the following sections we look at the data for the various areas.

Industrial - These customers are in the DG5 or DG6 group and as mentioned, the team acquired accurate granular data during the RegEnergy project of a number of Industrial premises in the area. Electrical bills were also secured for other premises, and these were converted into a profile comparing their size and industry type to existing data. Consumption profiles for businesses can vary much more due to factors such as the size of the business and the type of work involved. One business could be a standard office operating between 9am-5pm, while its neighbour could be a fish processing plant with 24/7 load that needs to occasionally generate ice and constantly maintain sub-zero temperatures in its cold storage spaces. Information acquired from the other businesses in the park has allowed us to build an aggregated profile for all the factories.

Agriculture - The West Kerry Dairy Farmers Sustainable Energy Community was created in 2019. They commissioned an Energy Master Plan to review the existing energy practices undertaken by the community and to then provide a roadmap for efficient, practical, cost-effective recommendations for energy efficiency measures for the SEC. The first step was to provide a high-level overview in the form of the Energy Baseline, by integrating monitoring systems. This provides a breakdown of the overall energy demand of the community. The anonymised data from a number of farms was supplied to the project which allows us to compare them with other profiles. Many farms are designated as DG2 meters and will often have demand profiles well in excess of normal DG2 residences. This agricultural data allows us to integrate these profiles into areas where it is known dairy farms exist and the load data at the associated ESBN transformer is higher than a normal batch of DG2 meters.

Services/Commercial - The RegEnergy project installed monitoring kits into a number of offices in the Milltown area and so, good, granular data is available for that sector.

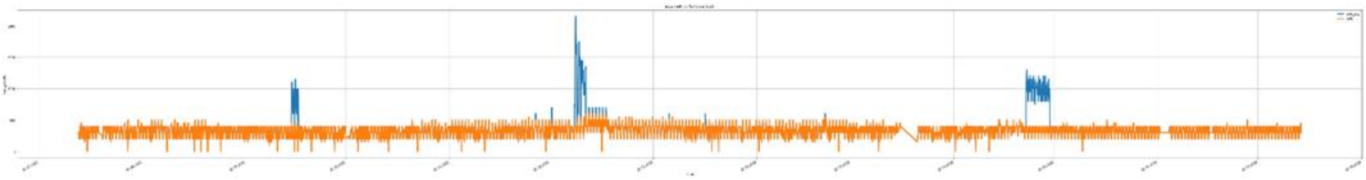
Public - This DG3 group covers items such as Public Lighting and is a smaller percentage of the areas load profile. Again, the majority of DG3 meters are in Dingle town and on the C17 feeder. Their location and the transformers they are fed from is also known so the data can be profiled in that area to suit these loads.

Residential - This sector covers DG1 and DG2 and it is assumed that an urban house will have a similar electricity profile to a rural one in Dingle. DG2 will also include some agricultural houses but not the farm. As this is the largest sector in the region, and granular local data was not available to us we employed specific modelling techniques for these profiles. As we cannot acquire data for every house in the peninsula, a residential load model was required to build profiles for typical houses. A number of open-source models exist for this purpose and after an exhaustive analysis process, the CREST model proved to be most accurate.

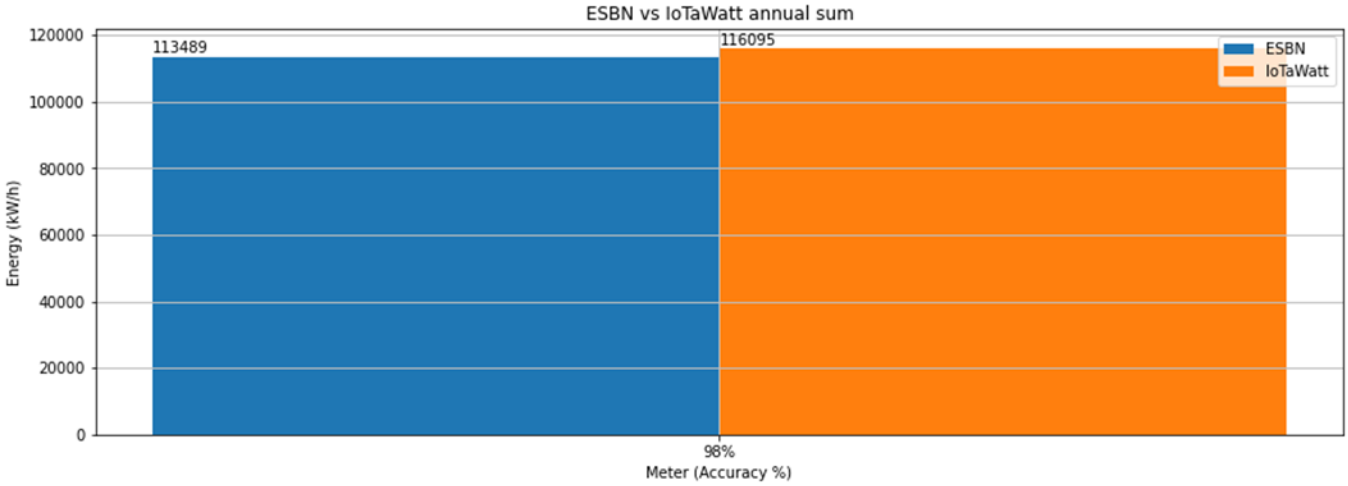
CREST Demand Model

The CREST Demand Model is an Excel spread sheet with Visual Basic Application code inside of it. It was created by Loughborough University in their Centre for Renewable Energy Systems Technology (CREST) department. It can define how many houses you want to simulate and selects a set of characteristics for each house. These include dwelling type (detached, terraced, etc), number of residents, primary heating system and more. Once each dwelling is assigned its characteristics, it will then simulate the resident activity of the house which in turn generates demand. Resident activity is heavily weighted towards daytime hours as most people are sleeping during most of the night. When the simulation is complete it will generate a spreadsheet reporting the total consumption for each minute in the 24-hour period. While the CREST model was originally intended to generate a profile for a 24-hour period, we require readings for 365 days. Instead of having to manually run the CREST Demand Model 365 times, code was added which runs the iterations automatically. The CREST model then allows us to build numerous profiles for the range of residence types and stochastically apply them behind each transformer on the E32 feeder.

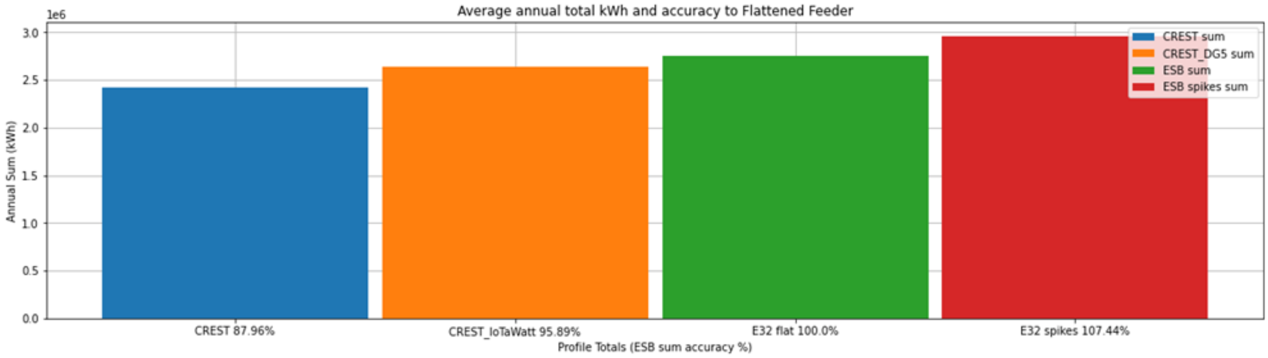
Using the CREST model and running it for the meters on the E32 feeder and adding the other loads from the businesses which we modelled from our smart metering data, we can arrive at a typical load profile for the entire feeder. The CREST data (orange) was then compared to the ESBN data (blue) and the results have proven to be very accurate – the spikes being maintenance issues due to storms where other feeders were connected to E32 for a short period.



Once the ESBN data is 'adjusted' for the spikes, both sets of data match well. This can be seen from the annual and monthly chart below.

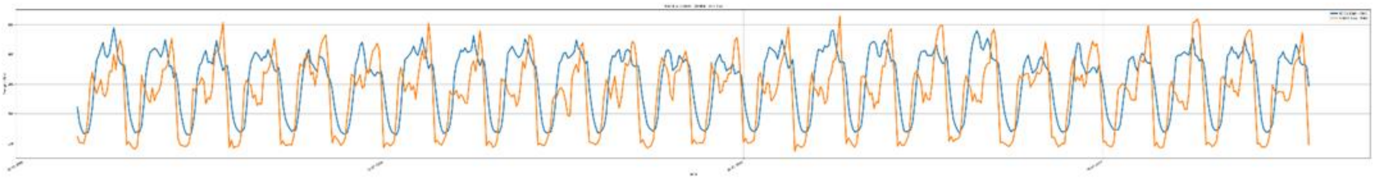


The CREST model data for all the residences on the E32 added with the businesses (orange bar) equates to 95.9% of ESBN's flow data (adjusted, red bar), see below.



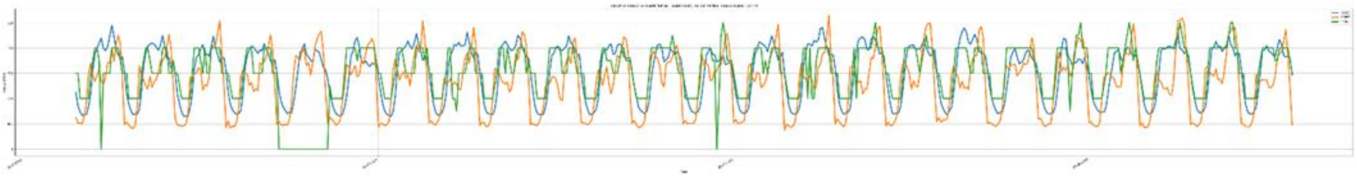
<u>**ISSDA Data**</u>

As previously stated, the CREST Demand Model is based on energy consumption data from the UK. The Irish Social Science Data Archive (ISSDA) is Ireland's leading centre for quantitative data acquisition, preservation, and dissemination. Based at UCD Library, its mission is to ensure access to quantitative datasets in the social sciences, and to advance the promotion of international comparative studies of the Irish economy and Irish society. The ISSDA's Smart Metering Project was conducted in Ireland and the SETU team used this data to further verify our results. The ISSDA project installed smart meters across 5000 homes and businesses and made the anonymized meter data publicly available. While none of the smart meters were located in Dingle, it's still a good dataset to compare the output of the CREST Demand Model. On the E32 Feeder we have 535 residential homes, so we took 535 readings from the ISSDA's dataset and compared the two.



NOTE: Blue: ISSDA, Orange: CREST

Of the meters used for this comparison, ISSDA's sample was for 3 weeks, not a full year, but still a reasonable amount of data to compare. The hours of high and low demand align really well; however, the CREST demand model's consumption is lower leading up to the afternoon and falls slightly lower during periods of low demand. This would suggest that the CREST Demand Model should be adjusted to match the ISSDA data better, but it tells a different story when both are compared to the E32 Feeder data.



NOTE: Blue: ISSDA, Orange: CREST, Green: E32

As there is a 12 year gap between the ISSDA data and the E32 feeder data, in order to be as accurate as possible we're comparing the same time of year (July 15th - August 8th). The same Root-mean-square error metric is used as when comparing the CREST data to the E32 Feeder and the result is as follows:

E32 - ISSDA: 92.58

E32 - CREST: 117.7

While the E32 data has 25 hours of missing data, this would've affected the RMSE scores for both data sets. We can see that the ISSDA sample set fits the E32 feeder better than CREST, but only by about 25kWh on average. The ISSDA data still peaks higher and drops lower than the E32 feeder, just not as much as the CREST Demand model. However, it does suggest that the output of the CREST Demand Model is nearly as good at fitting to the Feeder as real data.

Combined Load Model – From the ESBN databases, we know the type, number and location of all meter types on the peninsula. The CREST model can accurately model the residential meters (DG1 and DG2) and we have shown we have accurate models for commercial and residential loads (DG5 and DG6). The remaining DG3 - Unmetered Public Lighting, play a significant role in the C17 feeder and were modelled from their location. By aggregating the actual load models of industrial, commercial and residential models we have been able to develop a system to accurately build load profiles for the entire E32 feeder. The same process was repeated for the C15 and C17 feeders resulting in accurate models across the Dingle area.

The process began with the micro-EC in the Ballinaboula area and was rolled out along the E32 feeder line. This aggregated model was then compared to the actual load profiles provided by ESBN at each node for every hour of the year. This proved to be quite accurate, and a scaling system was deployed to further improve the models to represent the actual data.

The graphs below display the accuracy levels across a full year initially and then across a week to view how the models follow each other, hour by hour.

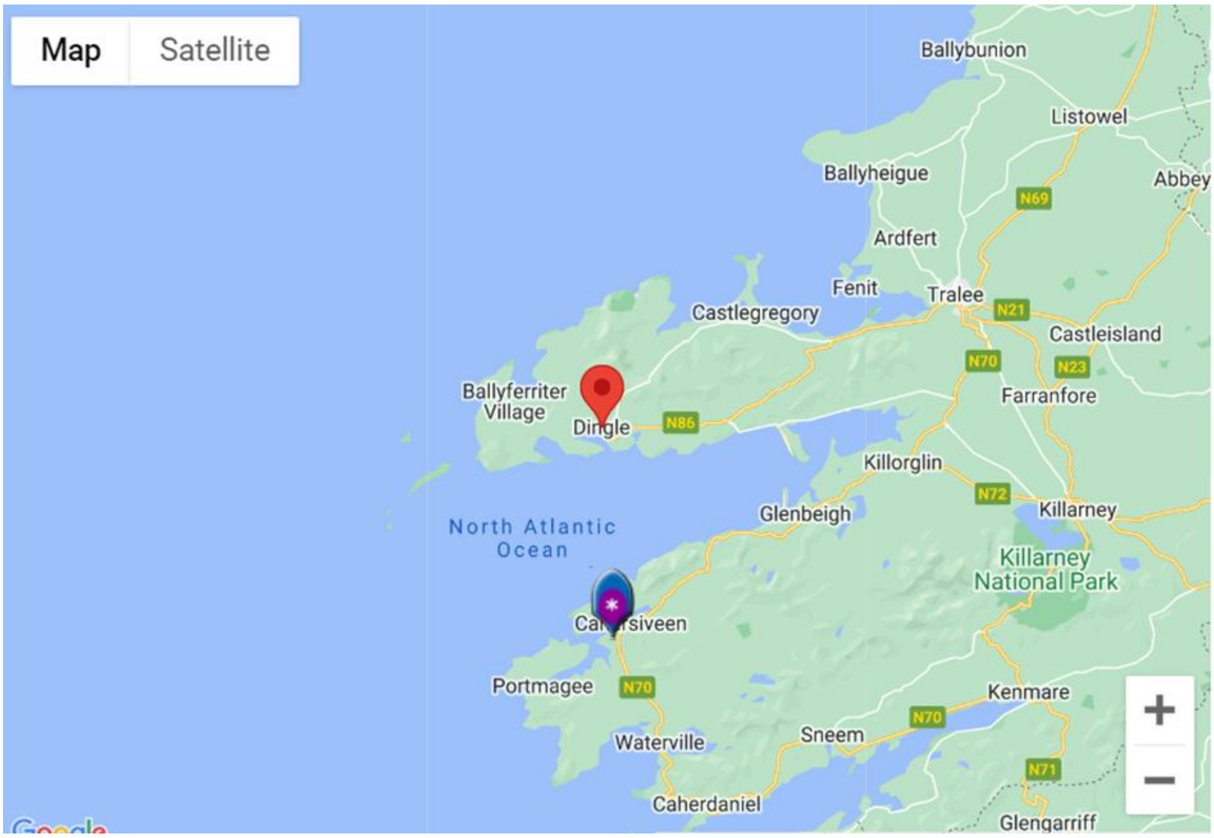
7 Energy Community Elements

In this section, we assess all the elements of an EC and how they relate to the Dingle region. In Section 6 above, we have shown how accurate load models were developed for residential, commercial, agricultural and industrial end users for a single feeder and then aggregated up across all feeders. We will now assess the data and methods to match this load demand with renewable energy supply aided by batteries and smart grid techniques.

Solar – Starting again at a micro-EC level, we can pick a subset of the load data to set up an EC in that particular area. We now need renewable energy data such that the system can be designed to maximise its self-sustainability. As the Dingle peninsula is designated as a scenic area it would be very difficult to integrate wind turbines, so we have focused on solar energy for this area.

There are many solar prediction systems and the team researched and decided upon PV Watts as the most suitable tool. It was developed by NREL, which is the national laboratory of the U.S. Department of Energy, and it estimates the energy production of grid-connected photovoltaic (PV) energy systems throughout the world. It allows homeowners, small building owners, installers and manufacturers to easily develop estimates of the performance of potential PV installations. It is based on the solar irradiance levels for the installs area and the models are built from weather data from the nearest station. PV Watts uses hourly typical meteorological year data, which is one year's worth of data that represents the solar resource over a multi-year period.

You can enter the location of your potential solar install and it will map its latitude and longitude of the solar resource data site along with the distance between your location and the centre of the site grid cell – the nearest weather station. In this case, Dingle is 15 miles north of the Valentia Island station below. This weather data spans many years and is used to model the weather patterns which include solar irradiance levels and cloud cover which feed into what a solar array may produce.



The main characteristics that effect the performance of a solar array are as follows;

- Pressure - atmospheric pressure
- Rainfall - rainfall (mm) for the period
- Temperature - air temperature
- Cloud cover - a percentage estimation of cloud cover
- Wind speed - wind speed (km/h)
- Wind direction - wind direction, 16 cardinal points of the compass
- Solar azimuth - position of the sun (E-W) in the sky
- Solar elevation - height of the sun in the sky
- PV array type - code for the type of PV installation
- PV module type - code for type of PV modules in use
- PV azimuth - direction the panels are facing
- PV tilt angle - angle at which the panels are mounted
- PV efficiency - percentage efficiency of the solar array
- PV losses - percentage losses in the PV system through inverter inefficiency, losses in transmission etc.

PV Watts gives an annual and monthly energy production estimates in kilowatt-hours, along with the monthly and annual average solar radiation in kilowatts per square meter per day. It also displays a summary of inputs with additional performance metrics. In general, you can expect the system's total electrical output for a given month of a particular year to vary by as much as ±30% from the long-term typical value. Similarly, the total annual output for a particular year may vary from the long-term typical value by as much as ±10%. The tool can then extrapolate out to every typical hour over the course of a year. This data can then be used to predict the energy profile for a solar array for the sites location which can be matched to the EC’s load profile.

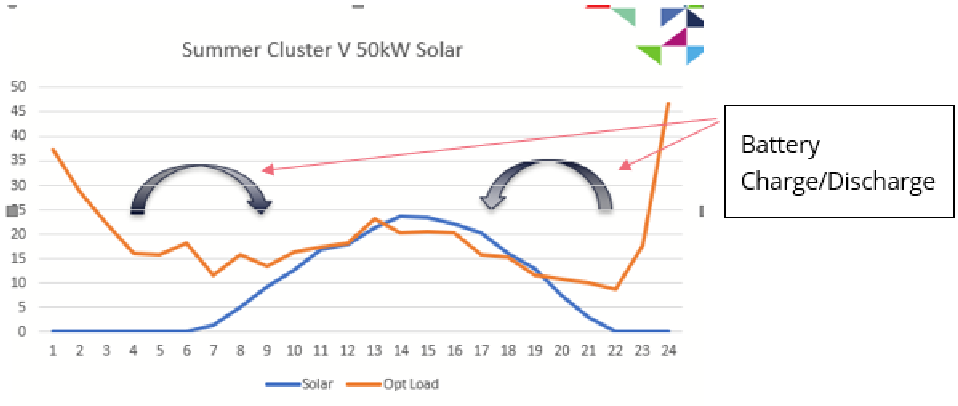
As mentioned, Wind energy has not been applied to the Dingle EC’s as planning permission would be difficult in this area. However, wind energy can be applied to EC’s in other areas and would provide a better aggregated generation profile when combined with solar as a more uniform profile can be achieved across the day and year.

Battery – The way we generate, transfer and use energy is changing, and our energy systems and infrastructure have come under increasing pressure to cope, resulting in significant black-outs. Energy costs are rising pushed up by fossil fuel prices and the expense of renewing ageing electricity infrastructure. As the proportion of energy generated from renewables like wind, wave and solar power rises, part of the solution to such intermittently generated energy is technology that can store the energy until it is needed.

Battery storage will form an integral part of the smart grid as it forms part of the solution to balance supply and demand profiles. Within an EC, it can be charged and discharged to suit the peaks and troughs of local demand and also for arbitrage with market pricing and ancillary services. The transition to produce energy from renewable sources must solve the challenges posed by the uncertain and variable nature of these intermittent energy sources and far more flexible power systems are necessary.

From an EC perspective, battery storage can play a key role in charging systems when excess solar energy is available and discharging when load exceeds generation. The charging/discharging of the battery can be employed to increase the self-consumption of the EC and improve its sustainability. Controlling its charge/discharge profiles will enable optimisation with existing solar energy, on-site load and market tariffs. Successful implementation necessitates analysis of the site’s environment, such as the type of energy load profiles, how seasonal they are, variability to time of day and whether any loads are flexible such that their timing can be optimised. Also, to compliment on-site generators such as solar the EC can avail of arbitrage with the market – you can charge systems at low prices and discharge at high. The system also needs to meet capacity requirements, charge/discharge cycles, ability to communicate with control systems, adequate life cycles, etc. and meet Sustainability goals and

Corporate and Social Responsibility. The graph below shows a typical application where a load profile is plotted with solar generation.



Battery Charge/Discharge

There are many factors in designing a battery system within an EC including type (chemical, mechanical, etc.), safety, size, etc. Other criteria include;

- Maximum state of charge (SOC) - battery capacity
- Minimum SOC (need to avoid complete cell discharge and damage)
- Maximum charge rate
- Maximum discharge rate

Key to creating an optimal battery usage policy is accurate prediction. The battery will behave in a predictable fashion in terms of charge and discharge, so the goal is to optimally use this to maximise the sustainability. The factors to consider at each step are:

- Predicted load
- Predicted renewables
- Electricity cost (can be wholesale or tariff based)
- Battery state of charge

Smart Grid Control Systems – The integration of more variable renewable forms of generation on the power system means distribution and transmission operators must consider an additional complex range of demand and supply issues. These include the operational challenges of switching to more variable non-synchronous generation sources, security of supply in terms of managing an increasing variety of generation technology types and the integration and use of Smart Grid technologies allowing greater user participation in the power system.

A major component of integrating these renewable energy sources onto the grid is the ability to forecast their output such that it can be matched effectively with demand.

Renewable energy forecasting is a rapidly evolving field and there is a continuous effort to adapt products to the needs of the forecast users. Renewable energy forecasting methods provide valuable information about the expected changes in the energy to be generated in the near future. These models aim to provide forecasts using historical time series data collected from certain points, such as meteorological stations, and a wind turbine or a solar panel. In order to further increase the forecasting accuracy, using information from areas close to the exact location where the forecasts are performed has gained importance. Moreover, the availability of data from different sources together with the emerging smart grid technologies, enabled especially by the development of advanced measurement and communication infrastructures, has paved the way for improved models.

System operators must put security of supply at the top of their priorities when integrating renewables. Therefore, their assessment criteria dictates that they must look at the capacity of the local network through a 'worst case scenario' lens. This means they will assess the implications of a potential renewable energy install on the basis that it is producing to its maximum and local demand could be at its minimum. As we have seen above, renewable energy is variable and intermittent in its nature and will rarely, if ever produce to its maximum. Also, capacity analysis of the transformers at the local substation is assessed under 100% back up availability resulting in a high level of redundancy in the system. These restrictive practices result in many renewable energy projects being rejected due to lack of local capacity in the network.

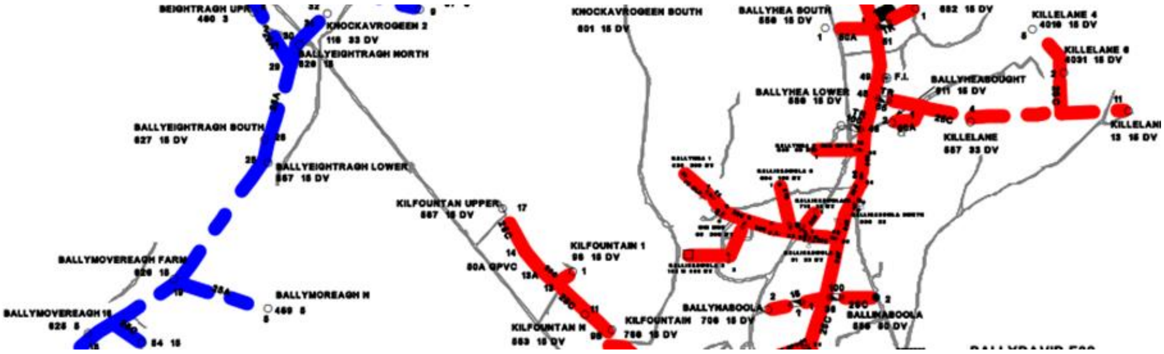
EC's are a potential solution to this issue. P2P trading facilitates direct energy transactions between two or more parties and facilitates prosumers to act collectively and take control of their energy profiles to generate, store, sell and share energy between themselves within a group. The concept of energy sharing has the potential to be the largest game changer in this transition. By aggregating the demand profile of all members of an EC it is much easier to design a renewable energy system to match.

Therefore, EC's can integrate far more renewables locally and match it to the load profile at all times of its members. They can use smart grid techniques and battery systems to balance supply and demand and maximise sustainability. In this way, members can generate their own energy and share any spill with neighbours that are adjacent to them, while spilling little or no energy to the wider grid. This is an intelligent solution to the capacity issues and sweats the grid assets in a much more efficient manner. Prediction and Optimisation systems are the enabler for these EC's to deliver on their potential.

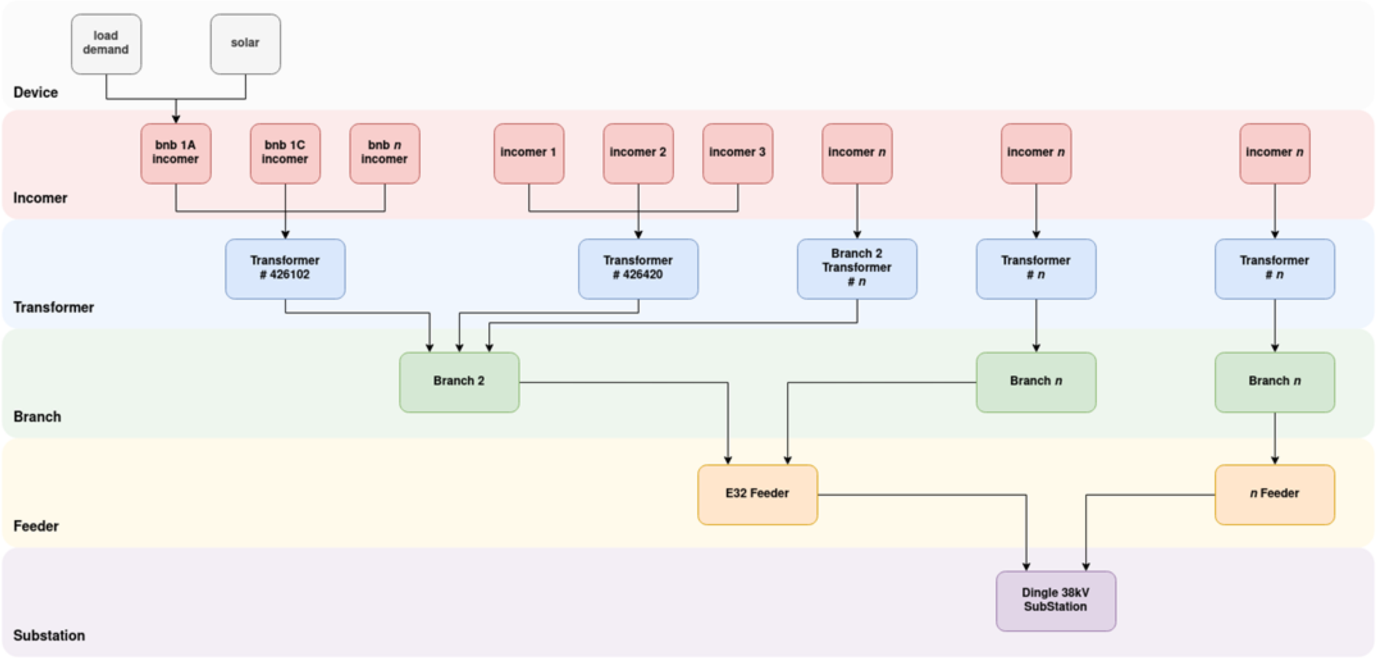
8 Design Strategy

With all of the elements and datasets of an EC secured – load, renewables, batteries - we must now develop a strategy that these elements can be combined to ensure their sustainability can be maximised. The above sections outline how load data models for every meter type in the peninsula were obtained resulting in an aggregated profile of the entire load. This was then modelled to the available ESBN flow models to generate hourly profiles across the entire year. Using mechanisms such as P2P energy trading then renewable energy (solar) and battery data can then be matched to balance supply and demand.

As detailed above, the network in the Dingle area is fed from a 38kV substation in the town along a web of 10kV and 20kV lines known as feeders. These feeders then supply electricity to the public via an array of transformers with a small snapshot of the network shown below. This network strategy caters for exactly how the electricity grid is outlined in a particular area.



Therefore, for the Sustainability software platform, the architecture of the modelling system needs to cater for a system of layers from the substation, feeders, branches, transformers down to individual load sites such as factories, houses and shops. Note, as we aim to make these areas more sustainable, these individual load sites may also have Devices connected to them which will affect their load profiles. This may be generation devices such as PV panels, loads such as heat pumps or a mixture of load and generation such as batteries or electric vehicles. Batteries and renewable generation may also be connected at the Transformer level. The Architecture below shows a graphical representation from substation level down to individual devices.



Referencing the above graph, each meter is an aggregation of meters above it. For example, the readings for ‘bnb 1A incomer’ is an aggregation of load demand and solar. Following on from that Transformer #426xxx is an aggregation of all the bnb incomer meters above it. Every meter at every level is an aggregation of the ones preceding it. The readings at the Device level are either gathered from real life data or generated using a combination of the CREST model and knowledge linked to the area.

So, the elements can be listed as follows;

1. Device: An individual device behind an incomer meter (heat pump, solar panel, battery, etc). Note, Devices can also be connected at Transformer level.

2. Incomer: The meter belonging to a unit/house/factory and is connected to the grid.

3. Transformer: An MV/LV substation that has 1 or many incomer meters behind it

4. Branch: A group of transformers that branch off from the main spine of the feeder.

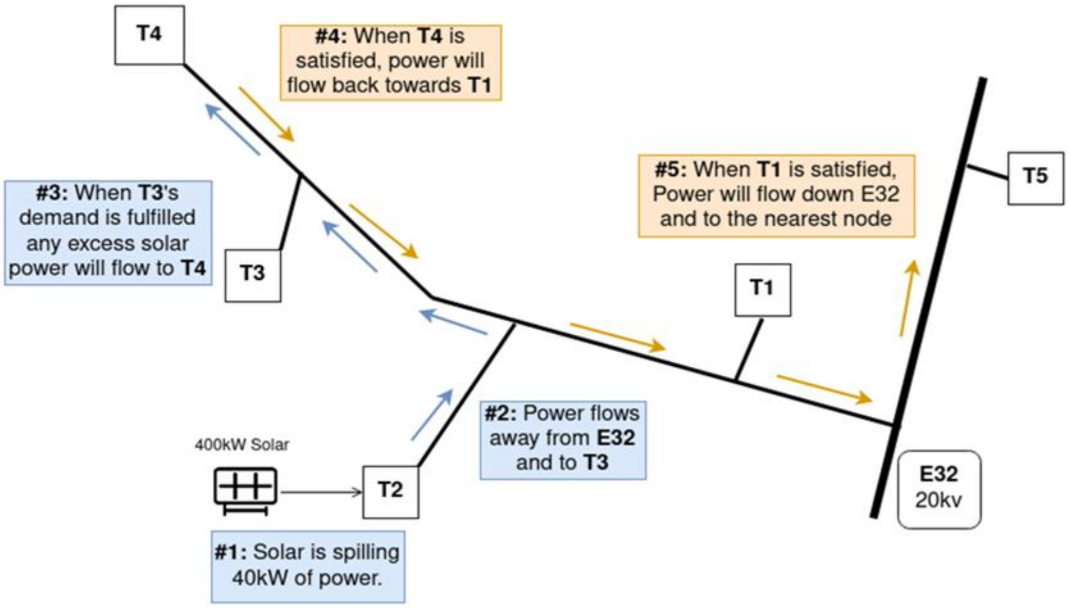
5. Feeder: An MV powerline that begins from the main Substation and extends outwards. Dingle feeders are either 10 or 20kV.

6. Substation: 38kV source of power for multiple Feeders.

Load Demand is the total demand that a building needs, and it can be satisfied via renewables and/or the grid. Most buildings are without renewables so, at the start, most load demand and incomer readings will be the exact same. However, when we go about adding renewables then these 2 meters will begin to look different. For example, at 12pm on a sunny day, bnb1A might have a demand for 5kWh, it's solar can account for 2 kWh so the incomer is only drawing 3kWh from the grid. It is important to have the Load Demand reflect how much energy the building is consuming, as renewables will become very dynamic and it's vital to have something that the renewables will be able to subtract from.

As energy sharing is based on being electrically connected to other EC members, it is critical the strategy conforms with the relationship between the members. It also must cater for what level of 'Devices' that can be integrated at any point in the network. Details of the sizes and capacities of all the elements is included from the substation down to the meters which dictates the size and number of devices, such as solar panels, that can be integrated at any point on the network. All data relating to each element and point of the network can then be represented in the system models.

An Energy Flow Strategy was then developed to cater for how energy will be shared within an EC when it is available. Substations, feeders, transformers and site meters are all physical elements and have a naming structure within the ESBN system. During the design of this project, the team introduced the concept of a 'Branch' as we are focused on creating EC's with entities who are electrically close to each other. As can be seen from the network diagram above, branches are fed from the main feeder line to provide electricity to entities in that area. These 'branches' feed a series of transformers and consequently, a number of load meters beneath it. A branch, or a group of branches could constitute typical EC's as they are a cluster of load centres. The diagram below shows a typical branch off a feeder with a number of transformers beneath it. Load meters will be connected to these transformers and generation and/or load devices may also be integrated at these levels.



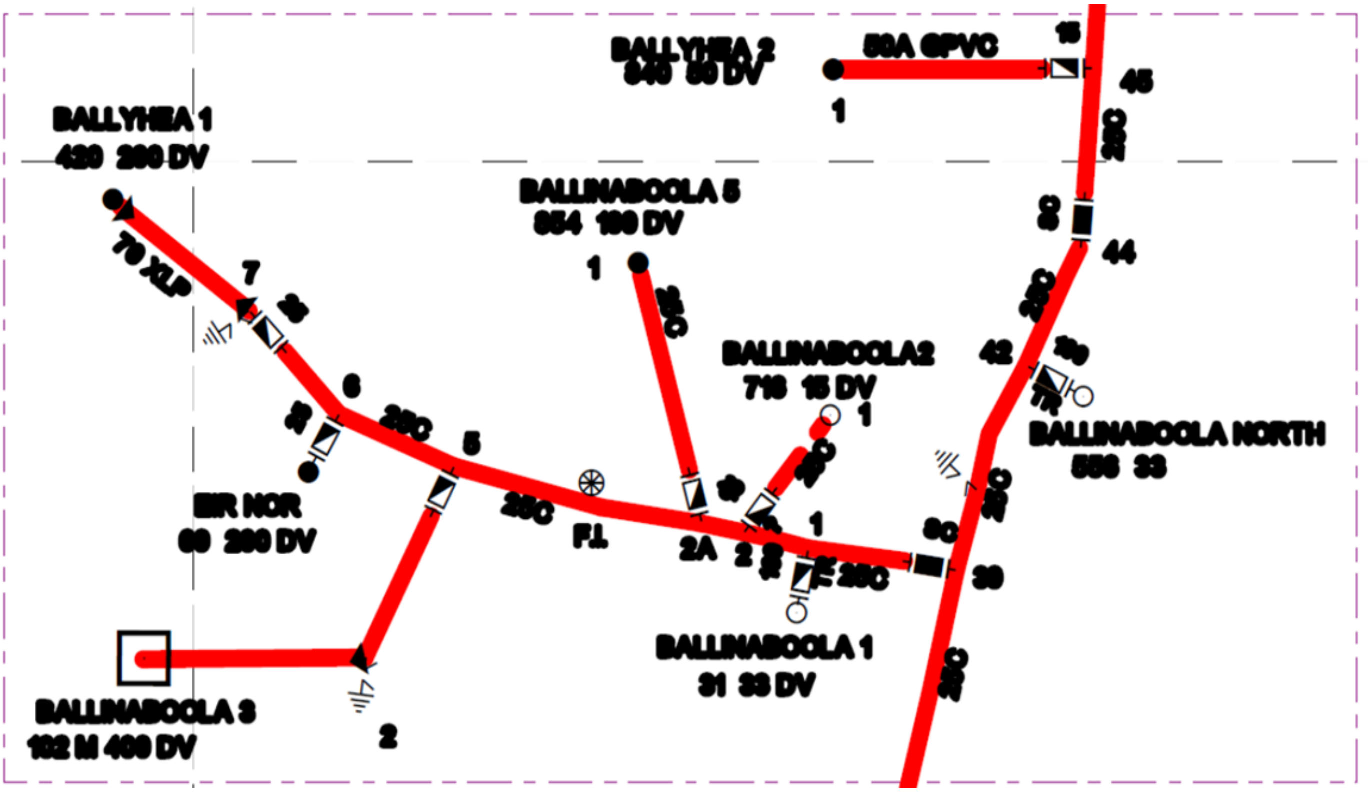
The Architecture and Network Strategies above cater for how the system handles all devices and elements within an EC. This strategy facilitates a Tree Structure to be applied with each element been given a 'Weighting' to each position, to represent its relationship to other elements in the tree. This dictates the relationship that each element has based on where the energy flows when it is available. From the diagram above, the system knows that when a transformer has sufficient energy for the metres beneath it that it will 'spill' energy downstream to the next point in the tree according to the weighting. As these branch clusters become more sustainable, they may spill energy back to the feeder if they have sufficient renewable energy and so, we need to have a relationship between this branch and the next downstream branch on the feeder. The weighting strategy is replicated when energy is spilled from a branch downstream to the next branch along the feeder. The network and its elements will have capacity limits as to the level of renewables and/or batteries that may be connected at any point. The system has enabled a rule-based system to ensure any network capacity constraints are catered for. A further constraint taken into consideration is a limit on maximum possible spill to the grid, the EC's MEC.

As there was a myriad of data sources, the team have developed a 'Master Database' of all elements within the Dingle area. Starting at the Dingle substation each 'Branch' is given an ID depending on its position on the feeder. The order of these ID's denotes the relationship between branches and what branches can spill to each other. Beneath each branch is the range of transformers which are each given a weighting to dictate the relationship between them within the branch for energy sharing purposes. The quantity and type of meters beneath each transformer is also listed which allows us to apply a load profile to each point. Geographic locational information is also applied such that the system can be displayed in a mapping format. Annual load data for each transformer is also included which is used to verify the load profiles from the models for each meter beneath them.

The steps to design a sustainable EC are firstly, to choose the branch or branches for the EC and generate a load profile from the system. Then, to maximise its sustainability, integrate as much renewable energy as possible to displace electricity from the grid across every hour of the year. As wind energy is not an option in the Dingle area due to planning laws, this model is based purely on solar. As solar output is variable and intermittent in nature across the year, we need to design a system that will provide as much energy as possible in winter periods and not too much in summer. If the solar system produces more energy than is required in the immediate EC it may be possible to spill it out on to the grid where surrounding areas may consume it. Any energy producer will have an MEC applied to it and it is predicted that EC's, as a group, will also have an MEC. ESBN will assess the capacity of the local network when setting MEC limits to a generator. ESBN regularly publish their 'Special Load Ratings' (SLR) for every substation giving ‘point in time’ loads for all feeders from that substation. The Summer Valley reading (lowest load in the year) for a particular feeder will give an indication of the minimum baseload of that area. Therefore, the MEC can be conservatively set to a level that the surrounding area will always consume any spill that an EC may export beyond its cluster onto the grid.

9 Local Renewable Energy Communities

To outline this strategy, we can create an EC from a number of branches on a feeder. From a Dingle perspective, we will begin with the micro-EC in the Ballinaboula Industrial Park as per the network diagram below.



From Section 6 above, this results in an aggregated energy demand profile across all the DG meters behind each transformer for every hour of the year. The table below is an extract from the database showing the details of each transformer and the number and types of each meter behind it for this EC.

Trafo's	**kVA**	10%	DG1/2	DG5	DG6
426102	400			11	1
426420	200		1	2	

426069	200			2	
426854	100			2	
426716	15		4		
426031	33		6	1	
426556	33		11		
426840	50		4		

The strategy then is to integrate as much solar as possible as per the solar models discussed above. As a cluster on the E32 feeder, an MEC is estimated for the Ballinaboula EC based on the capacity of the local network. We use the ESB Networks SLR to assess the lowest demand of the year on that point of the network. This is used in their ‘worst case scenario’ capacity analysis as the baseload and the level of demand that is always present to absorb any local generation. For the E32 feeder, the SLR is 200kW so we can run various scenarios through the projects Sustainability Platform with varying levels of EC MEC. As the first EC on the E32 feeder, the Ballinaboula Industrial Park EC was estimated at an MEC of 50kW, or 25% of the lowest capacity. For the entire E32, we can look at the SLR of the other feeders from the Dingle substation as an indication of the local baseload.

From a Solar perspective, we demonstrated the PV Watts system in previous sections. To apply this to an install across an EC, we need to assess the local characteristics. Much of the environmental data required can be attained from the weather station with the technical detail garnered from the specifications of the array. Others are site specific such as the PV azimuth and tilt. As there is ample roof space in the region, favourable roofs will be chosen when installing solar. An azimuth of 180 degrees represents a due south facing system which gives the best returns. However, buildings will face different directions and it will not be possible to use exclusively south facing systems. Therefore, we will use an array of azimuths from due east (90 degrees) to west (270 degrees). As south facing roofs will be prioritised, we have estimated a probability as per table below.

Azimuth	Probability %
90	12.5
135	20
180	35
225	20
270	12.5

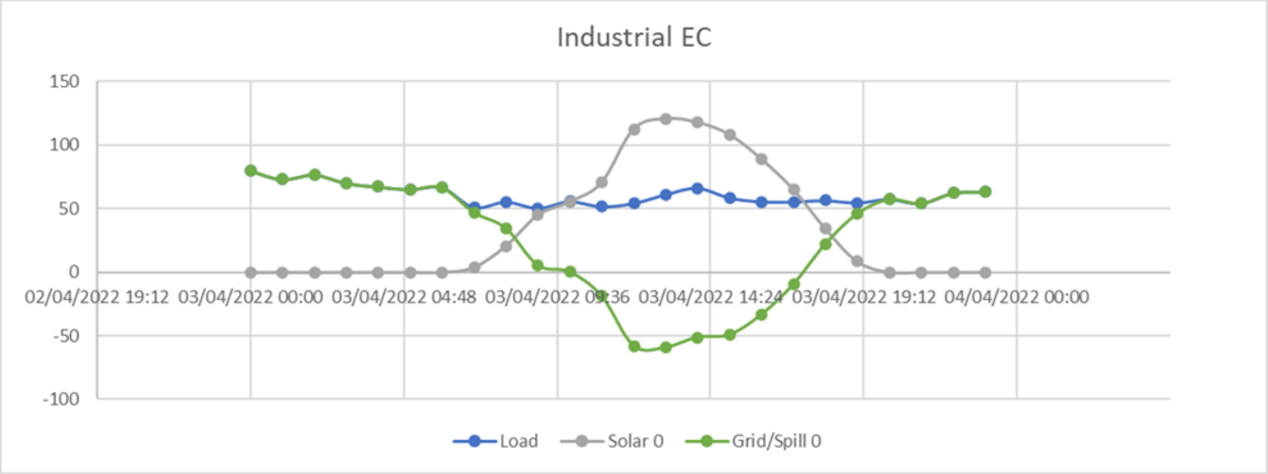
As all systems will be roof mounted, another factor is the tilt of the system. Analysis was completed of typical roof angles in the area and the following probability factors were deduced. As there is an amount of Industrial and Commercial premises with large roof spaces which may form the anchor tenants of EC's, lower pitch roofs were also included as follows;

Tilt (Deg)	Probability %
20	5
25	15
30	20
35	40
40	20

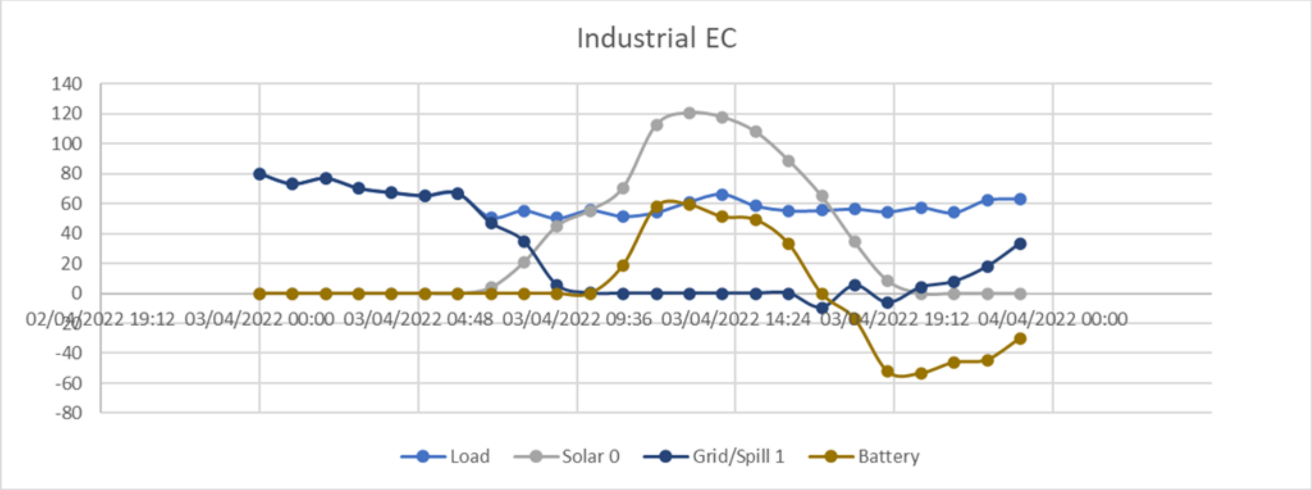
The PV Watts system was used to run the annual output for every hour of the year for a 1kw install for the Dingle location for every permutation of azimuth and tilt. The probability factor was then applied to each permutation which results in an average output taking into account all factors. These 8,760 values for every hour of the year can then be factored up depending on the size of the solar install to give an annual profile.

When designing a renewable energy system to balance the load profile of a region, you ideally require a generation source whose profile can mimic demand. The obvious drawback with solar is that it only generates in daytime and is very seasonal with significantly reduced output in wintertime. Wind energy is a very good 'partner' to solar in this respect with complimentary output profiles at night and wintertime. However, as Kerry County Council have designated the Dingle Peninsula as not suitable for wind development, we have not included it in the analysis. This significantly reduces the sustainability levels that can be achieved. Other forms of renewable energy such as Ocean, Hydrogen and Offshore wind technologies are not yet at a deployable scale to include in the analysis.

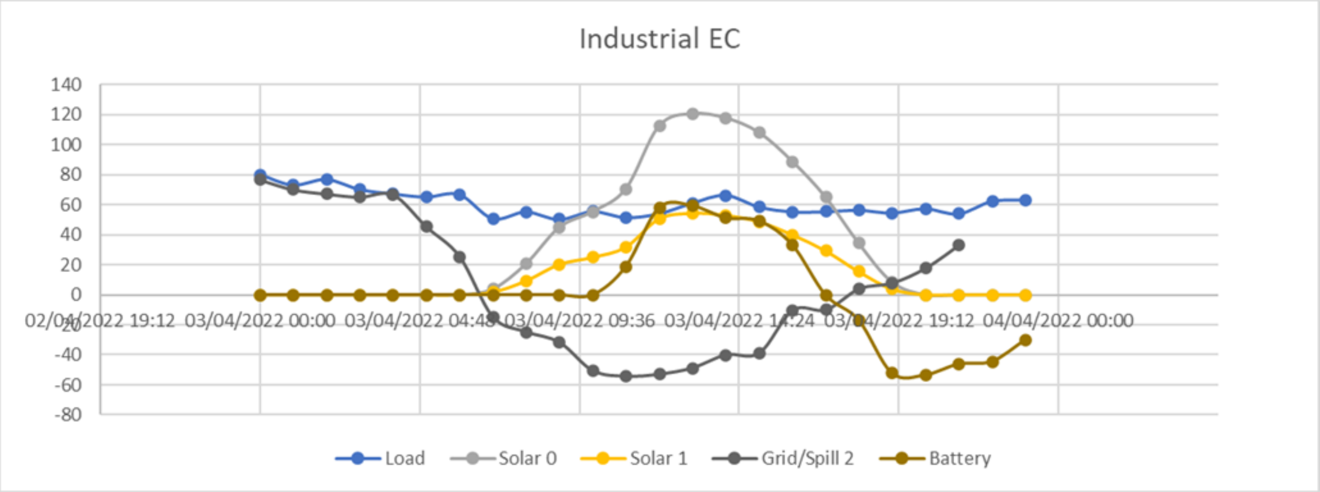
So, for the Ballinaboula Industrial Park EC, we have an aggregated load profile for all of the end users, an assigned MEC of 50kW and a Solar model which can predict output for this region across a range of rooftops. Battery systems will also be deployed to store excess output and remain within the MEC which can be discharged at nighttime to offset load. The steps to design a sustainable EC are firstly, to increase the integration of solar capacity until the 50kW spill level from the EC is reached in any single hour – which occurs in early April when solar levels are increasing and load levels were low, as represented in the graph below. This occurred with a solar install of 155kW.



The next step is then to introduce a battery system into the EC that has the capacity to charge with the level of spill available, effectively bringing the MEC back to zero again. A battery system of 270kWh would be required in this instance. As can be seen in the graph below, this removes the spill, and the battery can then be discharged to offset load in the evening/nighttime to reduce requirements from the grid.



This then allows us to integrate more solar into the EC represented by Solar 1 in the graph below which is a further 70kW solar array. Theoretically, we can continue to add more battery and solar in an iterative process, continually improving sustainability. However, the battery system would get very large and would not be practical so only a single iteration is included in the models. The platform will perform this process in an automated manner giving sustainability reports for potential EC designs.



From a Ballinaboula perspective, we have reviewed the available roof spaces of the industries and residences within the EC and there is ample space in south facing areas to accommodate the required arrays. There is also ample room and capacity to integrate the required battery systems as can be seen in the figure below. With an MEC of 50kW, the EC can attain a Sustainability level of 25%. Increasing the MEC to 100kW, which enables the integration of more solar and battery, increases the Sustainability to 32%.

Ballinaboula Energy Park

REC of 20 Factories and 52 Houses

Annual Load – 748MWh

MEC – 100kW

261kW Rooftop Solar

Industrial & Residential

640kWh Battery System

Sustainability 32%

10 Heat & Transport

With data made available from the Dingle Hub SEC EMP, transport is the largest energy vector in the region, followed by heat and then electricity. To achieve the goals of the clean energy transition, transport and heat which are currently wholly supplied via fossil fuels, must be electrified. They can then potentially be supplied from renewable sources. Electric Vehicles (EV's) and heat pump (HP) technology are both in their infancy in the Dingle area. However, various research projects, including the ESBN Dingle Project, have completed live pilot trials on integrating both technologies with stakeholders in the community. This resulted in valuable data on the usage patterns as stakeholders converted from fossil fuel sources to electrical.

We can take this data as heat and transport are electrified and build models on the spectrum from 0 to 100% electrification. These models will reduce the fossil fuel requirement and increase electricity demand. As we have a breakdown of the energy vectors from the EMP, we can supplant this increased electrical load on the network in relation to heat and transport at residential, commercial and industrial meters.

Transport Data - The penetration of EV's is growing as we electrify transport in the Clean Energy Transition. The team researched a number of data sources to garner typical EV charging profiles that would reflect a rural area such as Dingle. The most appropriate study from the research was found to be a Norwegian study completed from a housing cooperative located in a suburb of Trondheim, Norway. The growth in the number of EVs has led to an increased demand for residential charge points. In a survey from 2019, 94% of the EV owners living in single houses state that they charge at home weekly or more frequently, while 67% of the residents in apartment buildings state the same. Field data from 6,878 charging sessions registered by 97 users was available giving hourly predictions based on data sources frequently available for residents.

EV charging habits in the study are analysed showing the daily distribution of EV plug-in and plug-out times during weekdays and weekends, and histograms for connection times (related to plug-in time) and energy charged (related to plug-in time and connection time). EV charging habits are analysed separately for private and shared charging points. The daily distribution of plug-in and plug-out times is compared to hourly traffic data from nearby locations. This data was compared to Irish data where both regions have an average of 10 – 12,000 km per annum travelled. Therefore, the charging profiles for both areas would be similar.

Power use during residential EV charging is typically 2.3 kW when using a household power plug (10 A) and 3.6 kW or 7.4 kW when using a Type 2 connector (16 or 32 A). Both types of chargers are used and as users typically only charge their cars every couple of days, we could not simply take an average profile and apply it to Dingle. To take account of different chargers and regimes, the platform chooses random profiles from the range. In that way, if an EC consists of residences with, say 10 EV's, the random profiles over every hour of the year will give an accurate representation of the load demand.

Of the total number of profiles available, we only used private chargers and not public. As EV's in a rural area are predominantly owned at private residences, we apply these profiles to DG1 and 2 meters only (urban and rural residences) and not to Commercial and Industrial sites.

Heat Data - Residential buildings are a major contributor to energy consumption. In the European Union, the residential sector accounted for 26.1% of the final energy consumption in 2018, of which 78.4% are used for space and water heating and the remaining 21.6% are used for electric end-uses such as lighting or appliances. The share of electricity consumption is expected to increase with the rising relevance of heat pumps. In an area such as Dingle, with a relatively temperate climate, Heat may represent a smaller portion as highlighted in the Dingle EMP, but at 34% of total load it is a significant contributor to the overall picture.

The team researched various sources of heat pump data and found a study based in a district near Hamelin in Lower Saxony, Germany to be the most suitable to the Dingle area. The district consists of 68 single-family houses built in the late 1990's and early 2000s and they performed separate measurements in 38 households and an aggregated measurement at the electrical substation supplying all 68 households. This grouping represents a similar cross section to a rural Irish community with similar weather patterns.

Within the profiles there were a number which were incomplete, resulting in 18 valid datasets with a granularity of 1 hour. As heat pump profiles tend to be consistent across a daily basis within the seasons, average generated profiles across the range were used.

Application – The acquired datasets for both Heat and Transport from previous studies with applicability criteria to the Dingle peninsula, enables us to build scenarios as these sectors grow. The data can be applied to the geographic layout of the network in the area and apportioned at a per meter level across the peninsula. This enables us to apply HP and EV penetration levels to each meter and amend the load profiles of potential EC's as heat and transport are electrified.

This data is then applied via the software platform to calculate the effect of adding varying penetration levels of heat and transport which then calculates the effect of this on the Sustainability levels of potential EC's.

11 Legislation

Section 3 above outlined how the EU Directives – the Renewable Energy Directive and the Internal Electricity Market Directive - provide basic definitions and requirements for the activities of individual and collective self-consumption as well as for energy communities. Renewable Energy Communities in particular, allow citizens to collectively organise their participation in the energy system. Mechanisms within the Directives, such as P2P trading, have the potential to make a significant and lasting impact on the clean energy transition. Each EU jurisdiction must transpose these new laws into their national regulation, but each can implement the rules in a way that suits their respective energy markets. In this section, we will review the Irish and EU legislative landscape and assess potential routes forward for areas such as Dingle.

11.1 Irish Landscape

Although the EU Directives outlined above have been passed for some time, Ireland is well behind in transposing these into national law. Government bodies such as the Regulator (CRU) and the relevant government Department (DECC) have issued various consultations around Active Consumers which explores terms and other concepts around new energy activities such as aggregation, energy storage, demand response, flexibility, and energy sharing with interested stakeholders. There have been significant information gathering exercises through Calls for Evidence and Roadmap plans - however, there has been little progress in their implementation.

P2P Energy sharing is the mechanism which will facilitate the advantages EC's can bring to the network and local communities. However, the changes required to implement it are not trivial. It will require a significant shift in how the network is operated and controlled and the role of the DSO is central to this. Some aspects within the Directives on the structures of EC's are under consideration. These will be required as elements of an EC moving forward and may be 'mini steps' in a future, fully fledged EC. These include;

Small-Scale Renewable Electricity Support Scheme (SRESS) – this initiative is aimed at stakeholders integrating renewables above 50kW and potentially up to 6MW and having a government backed scheme to provide a floor price for the energy. The scheme aims to support larger non-domestic renewables self-consumers, such as farms, public buildings, commercial and industrial entities, as well as to provide a route to market for Renewable Energy Communities (REC's) and other small-scale solar PV developments. A reinvigorated support for Communities is one of the major pillars of the SRESS. A key design principle from the outset of the development of the SRESS has been to provide increased certainty in terms of a route to market for Community projects, who may struggle with the competitive nature of the previous RESS auction process. SRESS therefore, may enable EC's to develop their own energy projects but as they will spill directly into the grid at substation level, there won't be any smart grid aspects such as sharing to maximise their sustainability.

Proximity Clause – Proximity is a central component of EC's, particularly as it applies to the physical sharing of energy. Members of an EC must be connected to each other electrically on the same section of the network, either behind a substation, set of transformers or feeders such as when energy is shared between members that the actual electrons flow between them and supply and demand balancing can be maximised.

DECC recently issued a Consultation on the Proximity clauses of the EU Directives but did not include energy sharing. Instead, they focused on the Governance and Legal structures of a REC and how Proximity relates to it. SRESS projects offer local communities the opportunity to engage in the energy transition, normally connecting mid-sized generation to the local substation. These projects, by nature, are less technical than P2P and the Proximity issues are related to Control and Membership of the REC. For the energy sharing type REC's, Proximity is a more important issue and is more related to the technical issues of physical electrical network connectivity. However, this aspect has not yet been considered.

Private Wires & Networks – DECC recently issued a Consultation to assess stakeholders' opinion on the use of Private Wires & Networks as a mechanism towards integrating more distributed generation to assist in meeting climate action targets. Private Wires could potentially provide an off-grid solution for the generation and supply of electricity in Ireland. Currently, the ESB own the national grid infrastructure in Ireland and are the only body permitted to operate a network outside of private lands. However, if Private Wires were permitted, this would allow parties other than ESB to own electricity infrastructure, outside the confines of their own property, and to transmit electricity over this infrastructure. This could potentially open up opportunities for distributed generation assets to be connected to industrial loads on adjacent lands. Interestingly from an EC perspective, the Consultation also discussed the potential of Private Networks, which could facilitate the development of Renewable Energy Business Parks. These projects would see the development of a privately owned, operated, and maintained electricity network, at either distribution or transmission level, for the purpose of supplying power to a business park's residents. Projects of this nature are, for the most part, aimed at providing clean renewable energy direct to large energy users sited within a business park.

This effectively could achieve what is required in a P2P energy sharing REC albeit with a private network running in parallel with the national grid. While it is encouraging to see such mechanisms being discussed, it would be more beneficial to progress P2P sharing espoused in the EU Directives and maximise the use of the local grid already in situ.

Installed Capacity Cap (ICC) – The Irish grid is designed with excess capacity to cater for ‘worst case scenarios’ which rarely if ever occur. A solar or wind install will never export its full MEC. CRU recently issued a Decision Paper indicating its intention to remove the ICC, allowing generators to “over-install” once they don’t breach the contracted MEC. This will mean that generators can use smart grid techniques to increase their installed capacity to ensure they are exporting closer to their MEC and ‘sweat the assets’ of the grid they are paying for.

From an EC perspective, it is important that they have also included Hybrid co-located sites in the response. This can mean that a mix of solar, wind and battery storage could be used at a site and using Prediction and Optimisation mechanisms, maximise their output at strategic times. This ‘balancing’ technique is exactly how REC’s should work with on-site loads. Currently, the DSO’s legal connection point with their customers is their meter. However, for REC’s to prosper they should have their own designation with a ‘master’ meter at the entry/exit point of the REC. In this way, the REC could integrate the required amount of renewables to balance itself against its load profile while ensuring through its Prediction and Optimisation systems that its MEC is never breached. CRU realise that removing the ICC for Hybrid sites brings into play aspects such as sharing of MEC and the ability to have Multiple Legal Entities behind a single connection point. These aspects are also required for P2P REC’s and should be integrated across the network. It will also mean that ESBN will need to incorporate technology such as Export Limiting Systems and reverse relays to ensure MEC caps are never breached.

11.2 EU Landscape

Other EU jurisdictions have progressed more effectively in implementing the Directives. The following is a synopsis of the transposition progress in some other EU countries.

Portugal – individual and collective self-consumption (CSC) projects and projects for collective self-consumption in RECs are possible as far as they have an intelligent counting system and are installed at the same voltage level. Network tariffs for self-consumption using the public network are already in place, establishing the specific tariff levels. For collective self-consumption schemes connected by the public grid the tariff for the self-consumed energy is calculated taking into account only the tension level used (for self-consumed energy e.g. within a REC on low voltage level only low voltage network tariffs apply). If a self-consumption installation is located at a voltage level where reverse flows occur (i.e. from lower to higher voltage levels), the deduction of network use tariffs of higher voltage levels might be only partial. However, in practice, this is so far negligible. In June 2020, a new law was published that exempts collective self-consumption schemes to different extents from paying an element of the network charges called CIEG (Custos de Interesse Económico Geral). For individual self-consumption projects, 50% of CIEG costs are discounted, for collective self-consumption (including in but not limited to RECs) 100%. The CIEG are the costs of energy policy, environmental or general economic interests associated with the production of electricity and the costs of sustainability of markets.

Energy sharing is allowed within 2km for low voltage and 10km for medium/high voltage and the DSO is responsible for collecting and validating production and consumption data before sharing these with the involved actors. Projects above 1 MWp need a licence but are allowed. For CSC, anchor tenants are behind the meter, so no fees apply to their consumption.

France – Self-consumption in France is enshrined in law which contain provisions for individual and collective self-consumption. CSC is allowed if electricity is produced and consumed by several consumers and producers linked together through a legal entity. The DSOs (in France primarily Enedis) are required to equip each participant with a smart meter and implement necessary contractual and technical arrangements to facilitate self-consumption under transparent and non-discriminatory conditions. For CSC, a contract needs to be established between the DSO and the legal entity which identifies the different participants and determines the sharing scheme between the involved consumers. Net metering is not allowed for either scheme, avoiding that more electricity is treated as being self-consumed than the energy consumed within a short timeframe. In 2019, CSC was extended to a geographic distance of 2 km between the injection and consumption points with a cumulative power of the production facilities below 3 MW and 0.5 MW in non-interconnected areas. In a recent amendment, an exceptional increase to a 20 km distance between the two most distant participants is foreseen for isolated projects in areas of low population density. Can be LV or MV but can't be both.

Spain – Spain has an advanced framework on self-consumption in place, allowing to share generation among customers connected at low voltage within a distance of 500m. For CSC schemes, no grid fees are charged for the electricity exchanges within the scheme. In November 2021 Spain introduced variable distribution coefficients for CSC. The legislative proposal contemplates variable coefficients which must be established before consumption occurs and energy is generated, to avoid billing complications. For each consumer and participant in collective self-consumption, this coefficient will take the values that appear in an agreement signed by all consumers participating in collective self-consumption and notified to the distribution company as the person in charge of reading the consumption. The value of these coefficients may be determined based on the power to be billed by each of the participating associated consumers, the economic contribution of each of the consumers for the generation installation, or any other criterion provided that there is an agreement signed by all participants and provided that the sum of these coefficients of all consumers who participate in collective self-consumption is the unit for each hour of the billing period. REC's are only defined by their general purpose and nature.

Italy – In 2020, Italy has adopted a law on self-consumption and renewable energy communities, providing a general regulatory framework. It covers collective self–consumers of renewable energy with a focus on condominiums - natural persons or commercial actors, for whom generation and energy exchange is not the core business and that are located in the same building or condominium and Renewable energy communities (REC) involving natural persons, small and medium enterprises, local/regional authorities (e.g. municipal administrations), and private companies. Generation plants (individually not exceeding 200 kW) need to be located in the low or medium voltage network behind the same transformer station (MV/LV substation).

Italy set up an incentive scheme targeting self-consumption of RES geographically limited to the same MV/LV substation or at condominium level (CSC of RES). In both cases, within a "virtual" model, RECs and CSC schemes can join and exchange electricity through the public low voltage electricity network. For the electricity shared through the public network, members receive a refund for the electricity exchanged within the community. This refund represents the consumption-based part of the transmission/distribution losses related costs and amounts to 0,822€c/kWh of self-consumed energy (sum of the transmission tariff for low voltage users, equal to 0,761 €c/kWh for the year 2020, and the higher value of the variable distribution component for other low voltage users, equal to 0,061 €c/kWh for the year 2020).

For collective self-consumers, the tariff is further reduced by the network losses charge (1,2% for medium voltage and 2,6% for low voltage; variable depending on the voltage level and the hourly zonal price of electricity).

Austria – The DSO is responsible for collecting metering data and the quarter-hourly billing. The DSO must measure the consumption and the input of electricity. Furthermore, the DSO must provide the information to the community and to the energy supplier at the latest within the following day. All information must be available through an online portal.

Initially, the act supports private and commercial CSC (in e.g., multi-apartment buildings), including electricity sharing. In July 2021, a legislative package on the expansion of renewable energy which establishes a framework for RECs, while also provisions on CECs were introduced. For setting the level of reduction in principle, fees for using network voltage levels that are superordinate to the network voltage level in which the REC is located will be deducted for electricity exchanged within the REC. In addition, the volumetric tariff elements for surcharges are supposed to be deducted from the network tariff. The tariff reduction will be defined for low and medium voltage communities applying to all network areas. For the low voltage level, a reduction of more than 50% is discussed, for medium voltage communities a reduction of 30%. The losses DSOs make because of reduced network fees to participants of energy communities, would have to be compensated by consumers not participating in Energy Communities.

In summer 2021 Austria has established a Coordination Office for Energy Communities. Together with the public advisory institutions in the federal states, it will ensure that energy communities in Austria can be set up and operated easily and become an indispensable part of the energy market in Austria. The Austrian government will provide up to €4 Million to support the establishment of energy communities. Austria will also monitor compliance with the legal requirements for energy communities. In form of random or case-by-case checking of compliance the energy community needs to provide the regulatory authority with the data and information. The regulatory authority will publish an annual report on energy communities established in Austria, in particular on the number and regional distribution of energy communities.

11.3 Dingle Energy Community Potential

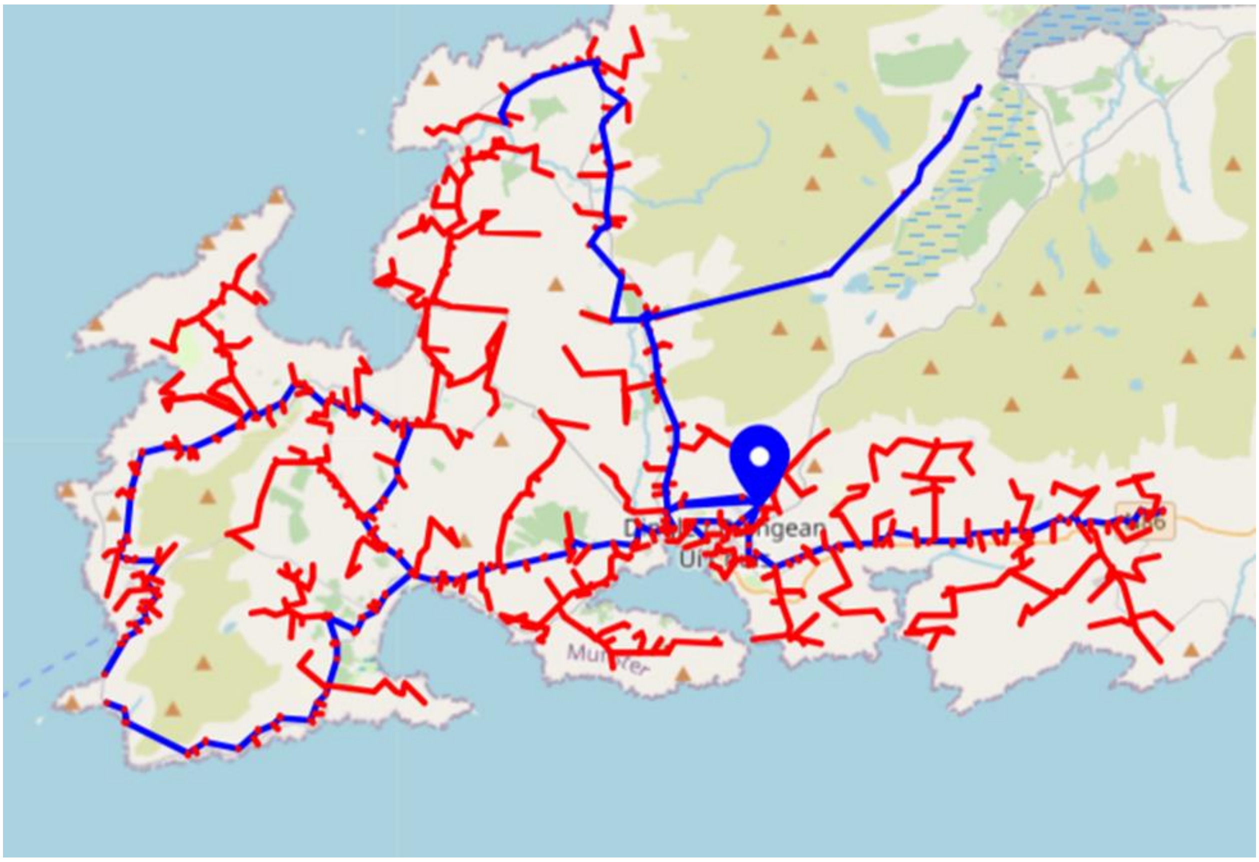
As there is a gap between developments for EC’s in Europe and Ireland, we need to assess what may be possible in the short and medium terms. The ‘mini steps’ that are under Consultation in Ireland will hopefully lead to an environment where full EC’s will be implemented. The Sustainability Dingle project has developed a software platform, and it is vital that its functionality can accommodate all scenarios that may accrue. Therefore, the tree structure and architecture enable the user to create EC’s based on a section of any network and design renewable energy and battery systems to balance its aggregate load. These EC’s can then be extended out along the network to roll out regionally.

12 Sustainability Dingle Software Platform

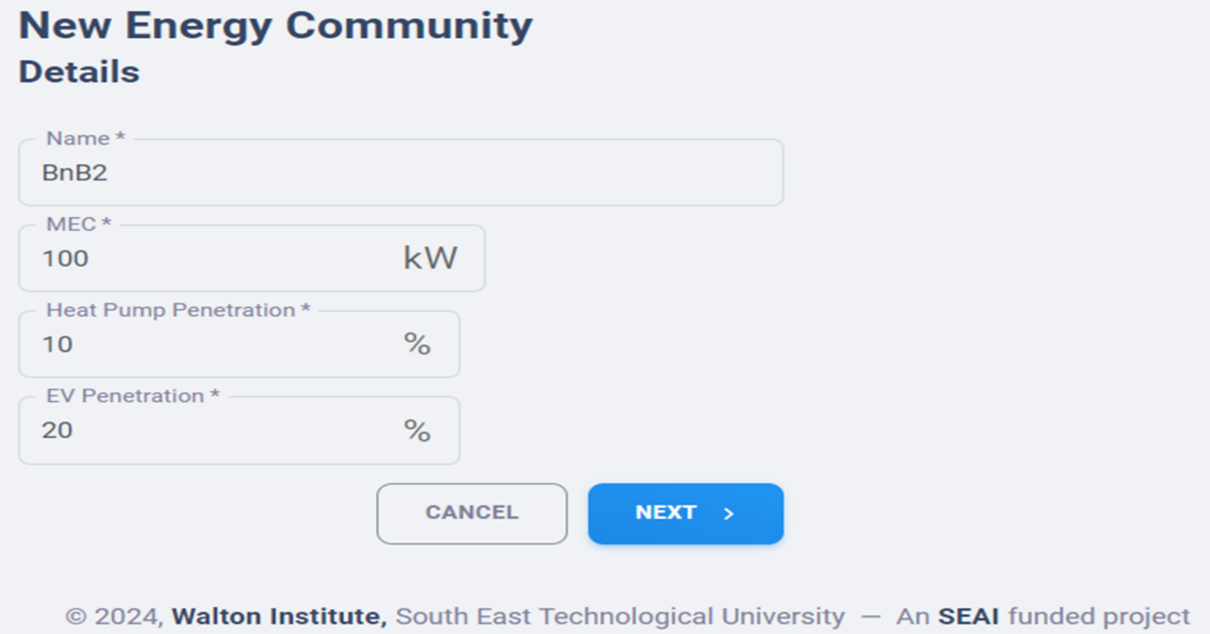
A major objective of the project was to design and build a software platform that would encapsulate all of the functionality above and enable an end user to develop EC’s along any portion of the network and sustainably balance it with renewable technologies and smart grid techniques. The team leveraged all of the available data to represent the local grid accurately and build models of the energy loads at every node in the network. It then facilitates the user to choose the branches on the feeder it wants to include in the

EC and aggregates them together to form an energy profile for every hour of the year. We outlined above the strategies the team used to incorporate all elements of an EC and how the system was designed to accurately reflect how it's sustainability can be maximised across the year. This section will give an overview of how all elements are represented and the functionality of the platform.

The architecture of the system was discussed in section 8 above and how the network is represented from substation level down to individual meters. The data of the local network was acquired, enabling the deployment of an accurate representation of the network in the Dingle region. There are 4 feeders coming from the 38kV Dingle substation and each of these distribute electricity to the peninsula via a series of branches and transformers supplying power down to the meter level at every site. The location of these nodes was made available to us which enabled a mapping of the network overlaid on the geographic area. The image below shows this on the platform with the main feeders in blue and the branches and sub-branches in red. The 4 feeders are the C17 Dingle Town supplying the immediate town vicinity, the E32 Ballydavid feeding toward the north, the C15 Ventry feeds towards the west and the E36 Lispole feeds towards the east. All feeders can be selected/deselected to isolate an area on the drop down on the map.



The sections above outlined the strategies behind designing an EC with the distribution of energy that is being shared within the cluster from its own renewable energy, that can be stored with the battery systems and flows to and from the grid within an allowable MEC. To create an EC, the user is brought to a page where they give credentials such as name, MEC and penetration of EV's and HP's.



New Energy Community

Details

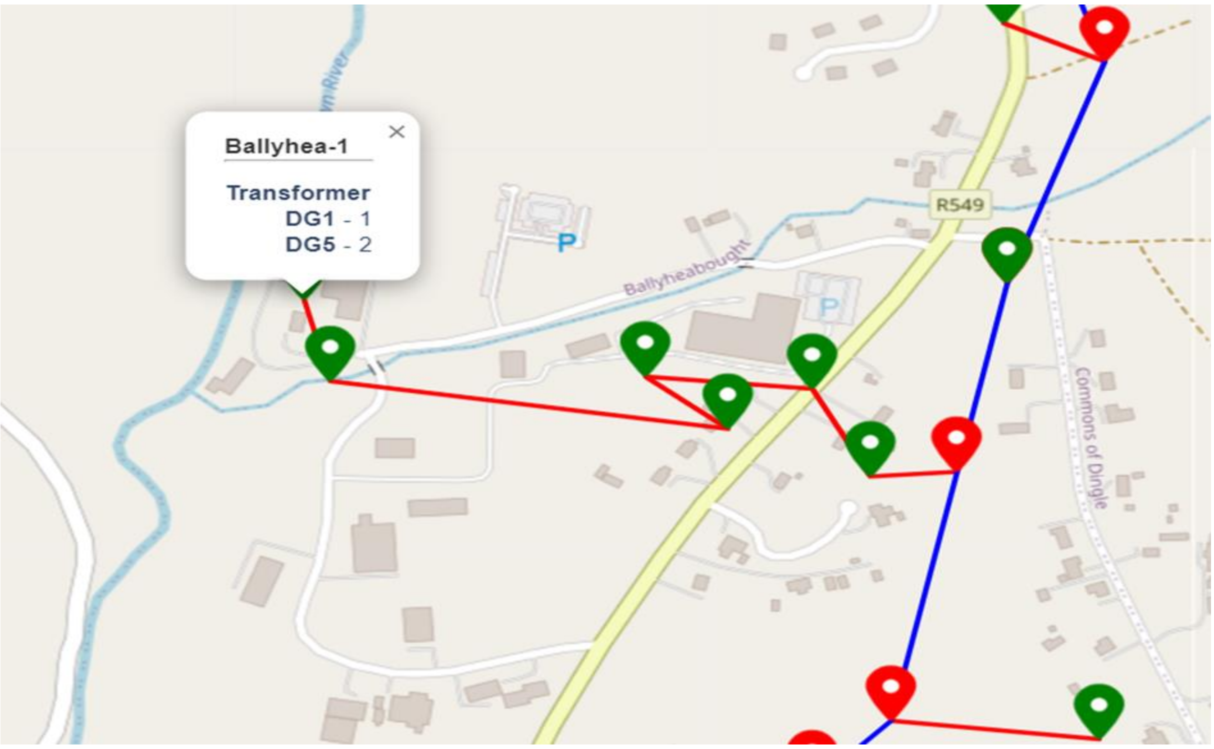
Name * BnB2

MEC * 100 kW

Heat Pump Penetration * 10 %

EV Penetration * 20 %

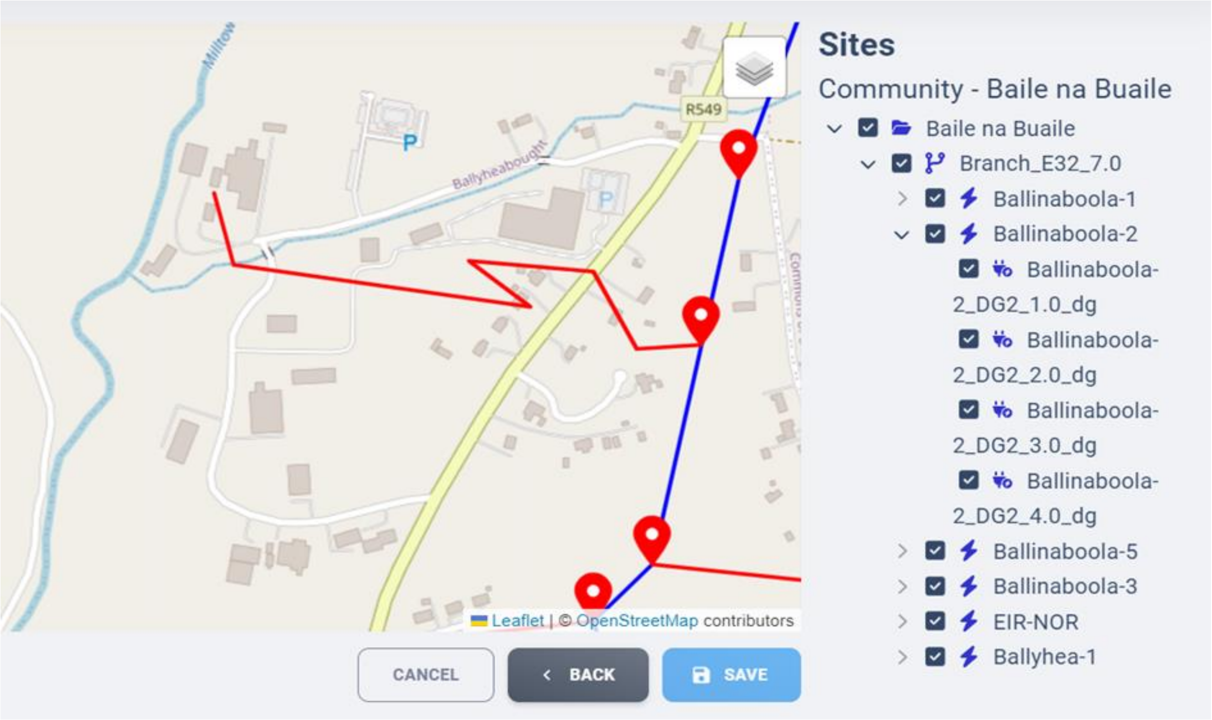
The platform then allows the end user to zoom in to the area of the map that they would like to create an EC and choose the first branch. The graphic below shows the example of the Ballinaboula area which has a mix of Industrial and Residential meters. Each transformer is represented by a marker which when you hover over it, you can view the number and types of DG meters behind it.



Ballyhea-1

Transformer
DG1 - 1
DG5 - 2

As described earlier, the architecture of the system is in a tree structure representing the network. As a member of an EC has the right to leave at any point, the platforms functionality allows members to be added and/or removed and the profile is adjusted accordingly. The tree structure, which has inter-dependencies between the branches, also ensures that as the EC is rolled out regionally that the members are physically connected such that energy sharing is possible.

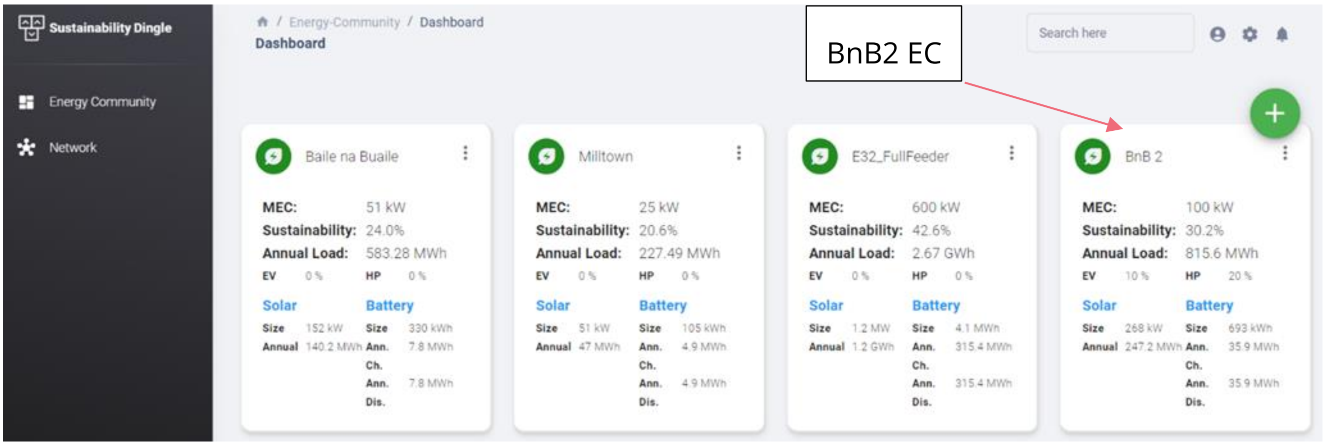


Sites

Community - Baile na Buaile

- ☑ Baile na Buaile
  - ☑ Branch_E32_7.0
    - ☑ Ballinaboola-1
    - ☑ Ballinaboola-2
      - ☑ Ballinaboola-2_DG2_1.0_dg
      - ☑ Ballinaboola-2_DG2_2.0_dg
      - ☑ Ballinaboola-2_DG2_3.0_dg
      - ☑ Ballinaboola-2_DG2_4.0_dg
    - ☑ Ballinaboola-5
    - ☑ Ballinaboola-3
    - ☑ EIR-NOR
    - ☑ Ballyhea-1

The platforms dashboard presents all saved EC's to the user in a tile format which shows the credentials chosen (MEC, EV and HP penetration) and the results (Aggregated load, level of solar installed, battery size and level of Sustainability achieved). The BnB2 tile is shown on the right.



Baile na Buaile
MEC: 51 kW
Sustainability: 24.0%
Annual Load: 583.28 MWh
EV 0 % **HP** 0 %
Solar Size 152 kW Annual 140.2 MWh
Battery Size 330 kWh Ann. Ch. 7.8 MWh Ann. Dis. 7.8 MWh

Milltown
MEC: 25 kW
Sustainability: 20.6%
Annual Load: 227.49 MWh
EV 0 % **HP** 0 %
Solar Size 51 kW Annual 47 MWh
Battery Size 105 kWh Ann. Ch. 4.9 MWh Ann. Dis. 4.9 MWh

E32_FullFeeder
MEC: 600 kW
Sustainability: 42.6%
Annual Load: 2.67 GWh
EV 0 % **HP** 0 %
Solar Size 1.2 MW Annual 1.2 GWh
Battery Size 4.1 MWh Ann. Ch. 315.4 MWh Ann. Dis. 315.4 MWh

BnB 2
MEC: 100 kW
Sustainability: 30.2%
Annual Load: 815.6 MWh
EV 10 % **HP** 20 %
Solar Size 268 kW Annual 247.2 MWh
Battery Size 693 kWh Ann. Ch. 35.9 MWh Ann. Dis. 35.9 MWh

The credentials can be edited and resaved as scenarios for review. Once the user clicks on a tile, they are brought to all the data, results and graphs for that EC. The graphic below shows this for the BnB2 EC. The Annual Load for the EC is 815.6MWh made up of Industrial and Residential loads. An install of 268kW of Solar will maximise its sustainability based on an MEC of 100kW. There is adequate south facing rooftops to easily accommodate this. A 693kWh battery would be required to charge itself on sunny days with low loads. As this is a predominantly Industrial area, we have kept the EV and HP penetration low at 10 and 20% respectively which yields a Sustainability level of 30.2%.

BnB 2
Ann. Load: 815.6MWh **MEC:** 100kW **Solar:** 268kW **Batt.:** 693kWh **EV:** 10% **HP:** 20% **Sust.:** 30.22%

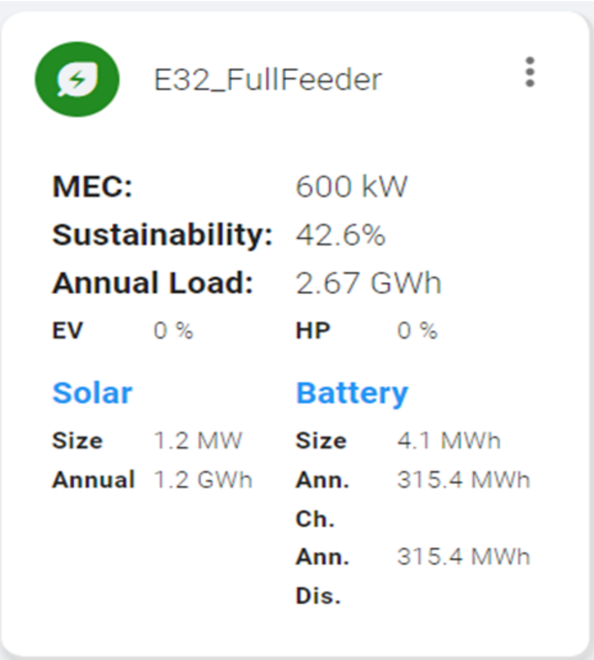
Monthly
Energy data by month

April
Daily energy data for April

As we can see from the 'Monthly' graph above, the Solar (pink) is obviously catering for a large percentage of the EC's load in summer but very little in the winter. In the 'April' graph, on the right, there are only 3 days where the EC is spilling to the grid (where solar production is higher than load and battery capacity combined).

The platform facilitates the user to drill down further into the data and select individual days and assess the flow of energy on an hourly basis, see graph below. If we choose the day with the greatest spill (April 16th), we can view the operation of the EC throughout the day. On the graph on the left, we can see that most of the load in April time is electrical (blue) with some EV (green) and HP (yellow) load at night with an average load of 75kW. The graph on the right shows the effect of adding renewable technologies to the EC. The battery is still discharging (orange) just after midnight until it is empty and can no longer offset load. As the sun comes up around 7am, solar (pink) begins generating and by 8am, it can satisfy the EC's load. The excess (green) is then used to charge the battery and by 2pm it is fully charged, and the excess solar generation is spilled to the grid (grey) – note it doesn't exceed the 100kW MEC. As the sun recedes, spill stops after 5pm and after 6pm, load again exceeds solar generation when we begin to discharge the battery which can satisfy load until after midnight. In this example, the Sustainability of the EC on this day could be closer to 200% with a max solar output of 200kW against an average load of 75kW. As the spill to the surrounding network is supplied from renewable sources, you could argue it is higher than 200%. However, as we are only using Solar, the Sustainability on winter days is low and this gives us an average score across the year of just over 30%. We will assess later in the Conclusions section the potential effects of adding wind energy.

This analysis is on a relatively small section of the E32 Ballydavid feeder around the Ballinaboula Industrial Park. The platform can then be used to increase the size of the EC, branch by branch, until the entire feeder is one large EC. As branches are added, the aggregate load profile is increased as the tree structure database has the number and types of DG's behind every transformer on every branch. The system then recalculates the maximum level of solar install and battery system the enlarged EC can sustain while maintaining spill levels below the set MEC. The MEC of the entire feeder was set at 600kW based on the ratings of the transformers at the Dingle substation and the summer load ratings of the surrounding area. The results are shown on the tiles below. On the left, the Scenario covers the full feeder with 0% penetration of EV's and HP's. The Sustainability score increases to 42.6% - this is a reflection of the fact that the remaining meters outside of Ballinaboula on the E32 feeder are predominantly residential and agricultural and their base loads are more daytime and therefore more suitable to be met by solar generation. As we see from the tile on the right where the Scenario is 50% penetration of EV's and HP's, the Annual load is significantly increased to 4.33GWh but the Sustainability drops to 27.5%. This is a reflection that both EV and HP profiles are skewed toward nighttime which reduces the ability of solar energy to meet them.

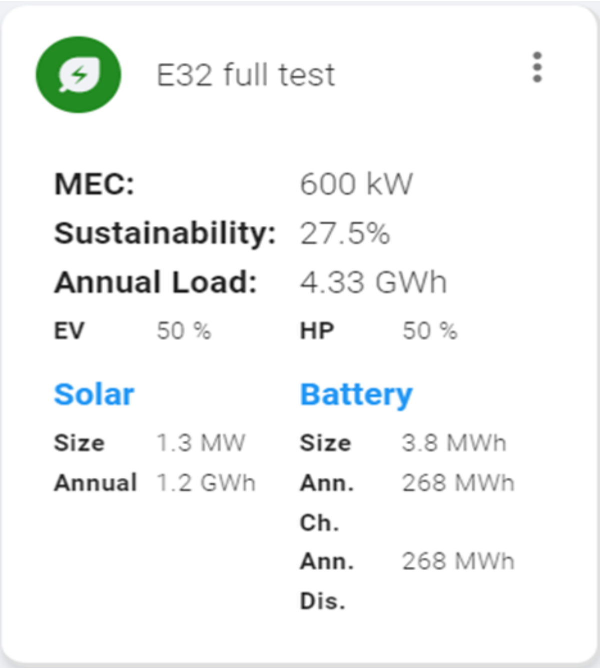


E32_FullFeeder

MEC: 600 kW
Sustainability: 42.6%
Annual Load: 2.67 GWh
EV 0 % **HP** 0 %

Solar
Size 1.2 MW
Annual 1.2 GWh

Battery
Size 4.1 MWh
Ann. Ch. 315.4 MWh
Ann. Dis. 315.4 MWh



E32 full test

MEC: 600 kW
Sustainability: 27.5%
Annual Load: 4.33 GWh
EV 50 % **HP** 50 %

Solar
Size 1.3 MW
Annual 1.2 GWh

Battery
Size 3.8 MWh
Ann. Ch. 268 MWh
Ann. Dis. 268 MWh

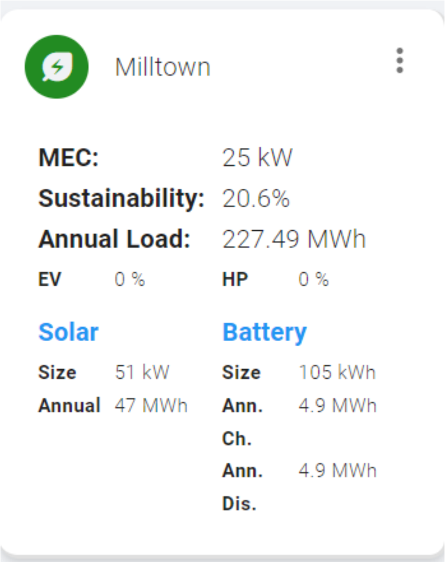
13 Project Results

The Sustainability Dingle Platform outlined above encapsulates all the functionality developed for the project. The previous section details the Ballinaboula EC and as its expanded along the network, the entire E32 Feeder EC and the associated Sustainability scores they can achieve based on various scenarios. Other EC's designed on the platform are outlined in this section.

Looking at scenarios in Dingle, implementing a private network in a single building is the easiest to integrate. The Milltown Office Block was discussed as a micro-EC where 10 individual offices are housed within a single block, each with their own meter located in a plant room. A group renewable energy and battery system can be deployed to balance the aggregate of the profiles. As energy sharing is not yet allowed and assessing the ‘mini steps’ under consultation in Ireland presently, a private network could be deployed by connecting each office behind the meter where energy is shared. Alternatively, a master meter for the building with a larger capacity could be installed with sub meters for each office similar to a shopping centre. This master meter would then be the legal connection point to the EC which can then maximise its supply and demand balance. Either option would be easily achievable as these meters are side by side and within the curtilage of UnG’s plant room.

Mechanisms from the Installed Capacity Cap decision paper could then be deployed as to the rules that the EC would have to conform to with the DSO to ensure capacity levels are maintained for the wider grid. The EC could be a hybrid site with a mix of solar and battery that can share its MEC with the ability to have Multiple Legal Entities behind a single connection point. Export Limiting Systems and reverse relays can be deployed on the DSO side to ensure the Optimisation systems never export more than the capacity limits set for them.

The Milltown EC was also designed on the platform with results as per graphic below. This EC is on the C15 Ventry feeder which has an SLR of 800kW and as this EC is relatively small compared to Ballinaboula, we set an MEC of 25kW for the cluster. An analysis of the load profile of the aggregated offices shows that there is a lot of night load as the block is heated with HP’s which are programmed to run at nighttime to avail of cheaper tariffs making solar a poor fit. Consequently, Sustainability results come in just over 20%. However, if an EC was developed here this load could be optimised to suit solar profiles.

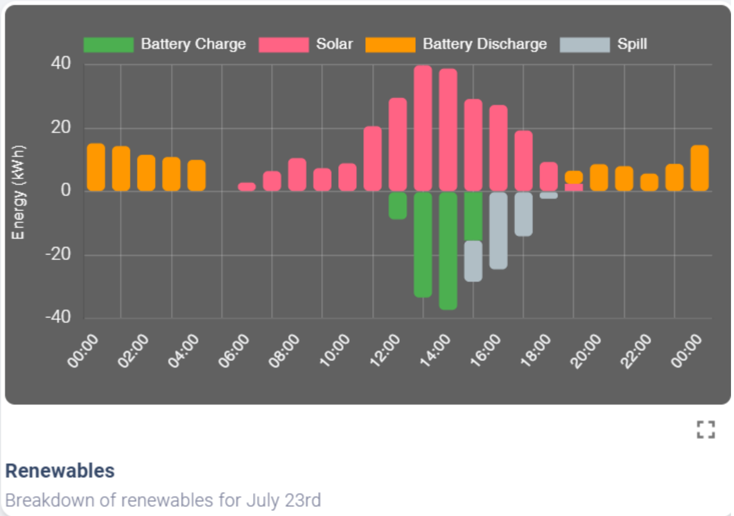


Milltown

MEC: 25 kW
Sustainability: 20.6%
Annual Load: 227.49 MWh
EV 0 % **HP** 0 %

Solar
Size 51 kW
Annual 47 MWh

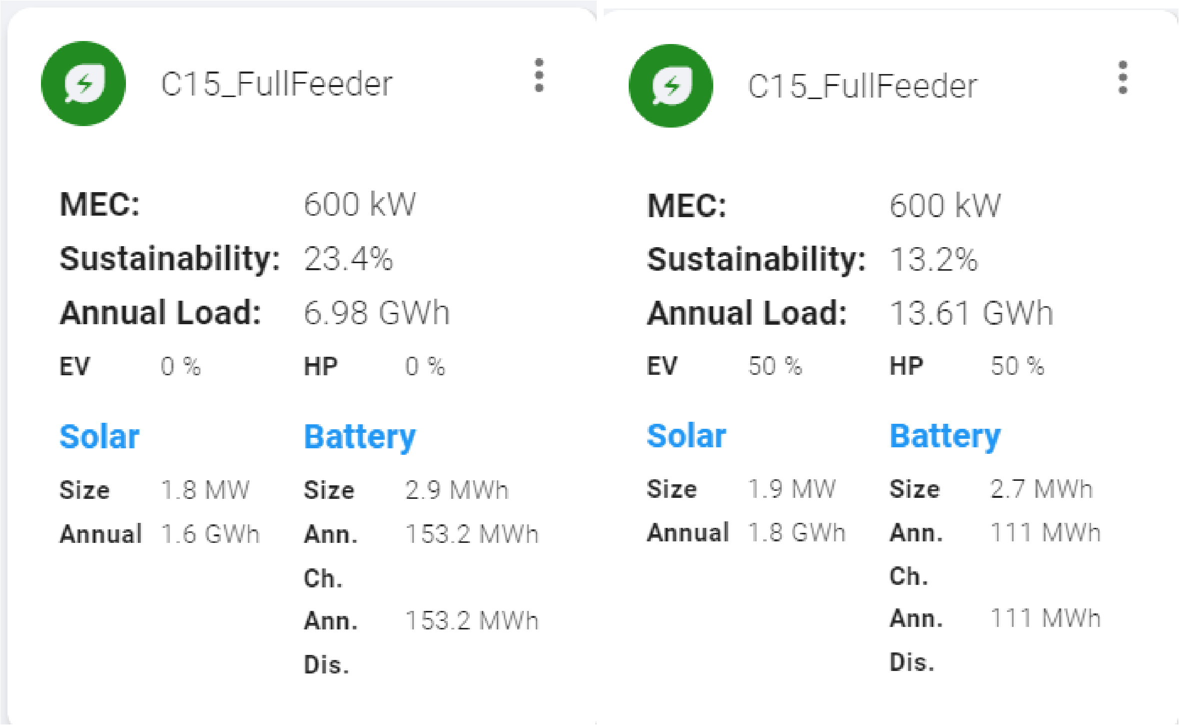
Battery
Size 105 kWh
Ann. Ch. 4.9 MWh
Ann. Dis. 4.9 MWh



Renewables

Breakdown of renewables for July 23rd

Similar to the E32 scenario, we can roll the Milltown EC out along the C15 Ventry feeder which supplies the western end of the peninsula. Results below show a Sustainability score of 23.4% with no HP or EV penetration which decreases to 13.2% when penetration levels for both are increased to 50%. These scores are generally lower than the E32 figures as it is a more rural area.



C15_FullFeeder

MEC: 600 kW
Sustainability: 23.4%
Annual Load: 6.98 GWh
EV 0 % **HP** 0 %

Solar
Size 1.8 MW
Annual 1.6 GWh

Battery
Size 2.9 MWh
Ann. Ch. 153.2 MWh
Ann. Dis. 153.2 MWh

C15_FullFeeder

MEC: 600 kW
Sustainability: 13.2%
Annual Load: 13.61 GWh
EV 50 % **HP** 50 %

Solar
Size 1.9 MW
Annual 1.8 GWh

Battery
Size 2.7 MWh
Ann. Ch. 111 MWh
Ann. Dis. 111 MWh

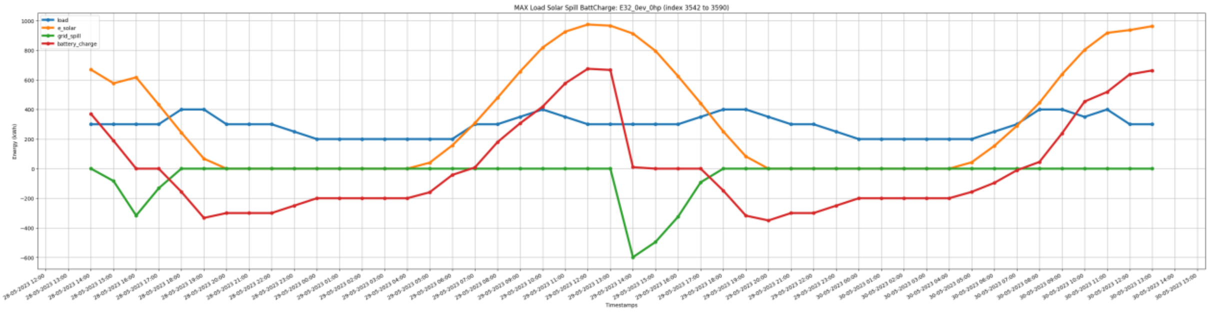
Similar scenarios were designed on the platform as outlined in the table below, where Balinaboula and Milltown are BnB and MT. Scenarios for the C17 Town feeder are also included. The E36 feeder was excluded as not all data was complete for it. However, the E32, C15 and C17 feeders cover everything out the peninsula from the 38kV substation.

EC	Solar kW	Battery kWh	Load MWh	MEC kW	EV%	HP%	Sustainability Score %
BnB	268	693	816	100	10	20	30.2
E32	1,200	4,100	2,670	600	0	0	42.6
E32	1,300	3,800	4,310	600	50	50	28.2
E32	1,300	3,600	5,970	600	100	100	20.3

MT	51	105	227.5	25	0	0	20.6
C15	2,100	2,300	9,570	600	0	0	20.4
C15	2,220	2,400	16,120	600	50	50	12.8
C15	2,200	2,200	22,690	600	100	100	9.2
C17	1,700	3,800	5,770	600	0	0	27.7
C17	1,800	2,900	7,940	600	50	50	21.2
C17	1,800	2,600	10,140	600	100	100	16.5
E32+C15	3,300	5,600	12,240	1200	0	0	24.9
E32+C15	3,500	5,800	20,470	1200	50	50	15.7
E32+C15	3,600	5,600	28,650	1200	100	100	11.4
E32+C15+C17	5,600	10,500	18,000	1800	0	0	28.4
E32+C15+C17	5,400	9,000	28,380	1800	50	50	17.6
E32+C15+C17	5,500	8,700	38,880	1800	100	100	13.1

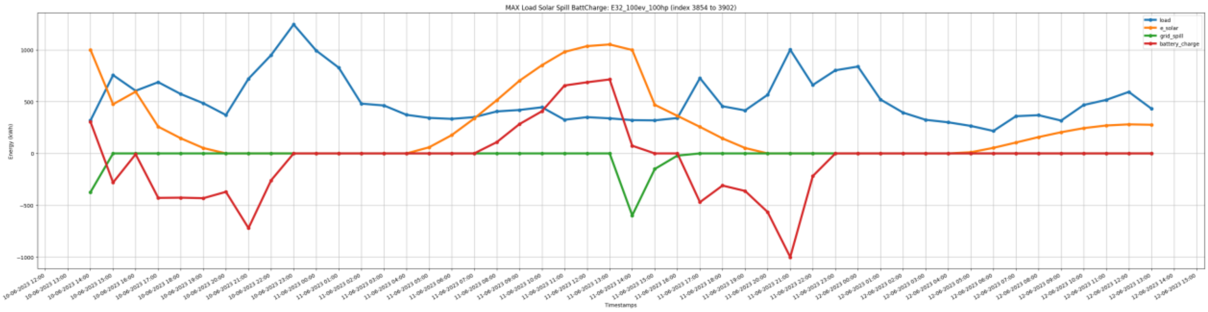
Interestingly, battery size decreases as we increase the penetration of EV's and HP's. The battery size is determined to consume the level of spill on the first iteration when solar is designed for the load profile but maintain itself below the MEC. This day will happen on a high solar day (summertime). As can be seen on a typical summer day in the graphic below for the full E32 feeder with 100% penetration of both EV's and HP's, the added load from this increased penetration is mostly at night and less likely to be met by solar. This leads to less periods of excess solar, so there will be less hours of excess solar before the MEC is hit, requiring slightly smaller batteries.

On the E32 with 0% EV & HP, MEC hit @ 29th June 14:00



GRAPH COLOURS
Blue = Load Demand
Orange = Solar Generation
Red = Battery Charger/Discharge (negative = discharge)
Green = Grid Spill

On the E32 with 100% EV & HP, MEC hit @ 11th July 14:00



Merging all 3 feeders E32, C15 and C17, supplying electricity to all the peninsula from Dingle town out, has a load profile of 18MWh with no HP or EV penetration increasing to 38.88MWh with 100% penetration of each. Sustainability decreases from 28.4% to 12.1% as heat and transport are electrified.

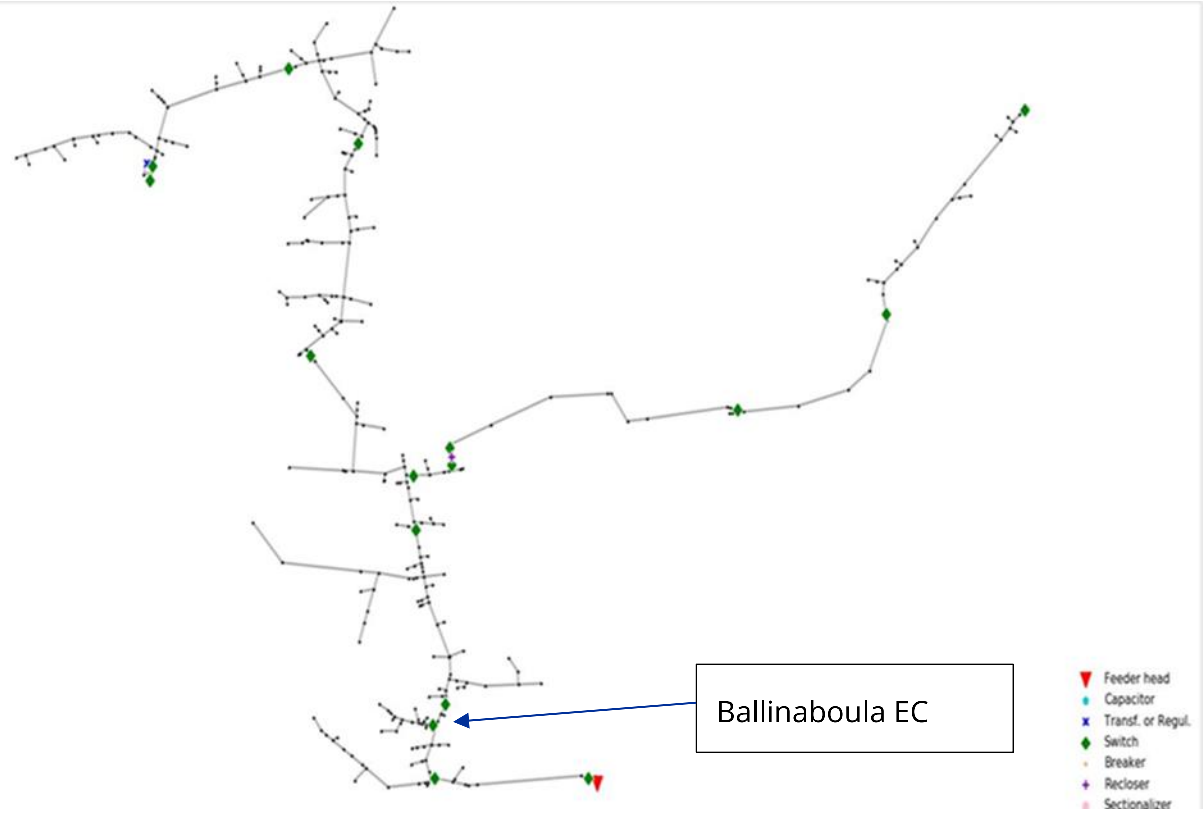
14 Electrical Capacity

The effect that EC's and their inherent smart grid techniques can have on the Sustainability of a region is obvious from the above results. However, if the existing grid requires significant and costly upgrades to facilitate them, they may never flourish. Therefore, to assess the practical implementation of EC's, an analysis of the Electrical Capacity of the Dingle network was completed to assess this radical increase in distributed generation. To analyse the effect on voltage change, line loadings, etc., we needed to bring external expertise in and engaged with Juan J. Cuenca and Barry P. Hayes of University College Cork who completed an in-depth study.

EC's present new challenges from a technical point of view: the intermittency of renewable energies creates significant local imbalances of supply and demand that may require advanced management techniques to keep grid stability. Distribution system operators must oversee that the application of EC's does not result in the technical limits of grid components being overpassed – electricity grids are critical infrastructure and keeping them safe is a top priority. ECs are then encouraged to implement technologies to control and balance electricity generation and consumption. We have seen in previous Sections how the local distribution network spreads over the peninsula like a spider's web.

This section focuses on the simulations performed in the electricity infrastructure to verify the impact of different EC study cases on grid security. Several scenarios of PV, Battery Storage, EV and HP penetrations were evaluated through extensive power flow simulation work to ultimately determine this impact on the E32 electricity distribution feeder in the Dingle Peninsula. The Dingle area has been the subject of several electricity grid infrastructure studies in the past and this knowledge was central to the modelling task.

As discussed above, the EC design strategy focused on beginning with the micro-EC around Ballinaboula and rolling out geographically along the E32 feeder, shown below. The electrical analysis followed the same process. We previously explained the process whereby an EC was formed in the Ballinaboula Industrial Park by aggregating the energy demand profile across every hour of the year. As solar and battery systems were integrated along with an appropriate MEC, the micro-EC was rolled out across the entire E32 feeder. MEC criteria for the Ballinaboula Industrial Park EC was set at 100kW and for the entire E32 at 600kW, as per the Sustainability reports above.



The electrical analysis followed the same iterative process analysing different combinations and sizes of technologies along the E32 feeder as well as integrating varying penetrations of Heat and Transport. The electrical simulations were run for the following scenarios;

- Case 0 (C0) is the base case (as now, with no EC's), where only base case electricity demand is considered.
- Case 1 (C1) is the effect of adding the Ballinaboula EC - first iteration of the optimisation process, including solar PV and Battery.
- Case 2 (C2) is the entire E32 EC with the inclusion of Batteries and PV installed.
- Case 3 (C3) as C2, but 25% of customers have one EV, and 25% installed a HP.
- Case 4 (C4) as C2, but 35% of customers have one EV, and 35% installed a HP.
- Case 5 (C5) as C2, but 50% of customers have one EV, and 50% installed a HP.
- Case 6 (C6 as C2, but 60% of customers have one EV, and 20% installed a HP.
- Case 7 (C7) as C2, but 80% of customers have one EV, and 10% installed a HP.
- Case 8 (C8) as C2, but 100% of customers have one EV, and a HP.

So, this results in an analysis on the effect on the grid of the micro-EC at Ballinaboula and then as this is rolled out across the E32 feeder. As heat and transport are electrified, we have various scenarios right up to 100% penetration. These can all be compared to the current base case scenario.

Simulation Results

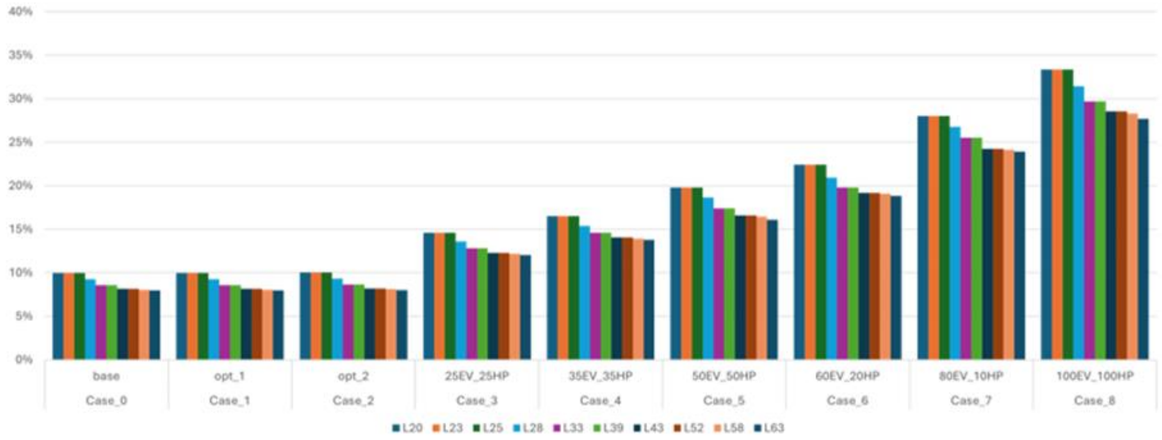
A computer model of the electricity grid was previously developed using the open-source electricity distribution system simulator OpenDSS, developed by the Electric Power Research Institute. This model allows power flow calculations to simulate the technical impact of installing different technologies, or different operational regimes virtually, without the need for physical deployment and measurements. This model is then ideal to test the different EC scenarios developed. The metrics used to evaluate the security of the grid are Line limits, Voltage change and Unbalance limits. Line limits are physical restrictions imposed by the current-carrying capacity of cables. Depending on their cross section, conductors can carry up to a certain number of Amperes (unit for electrical current). This value is given by the cable manufacturer and must be respected at risk of permanent damage of the cables, or the activation of protection devices.

Voltage is an important metric constantly checked in electricity distribution networks, which should not exceed or be under preestablished thresholds. In Ireland, this limit is between 90-95% for the lower limit and 105-110% for the upper limit, from the nominal voltage. This represents approximately a voltage bandwidth of between 18.9-23.1 kV for normal operation of the medium voltage grid of study, if these limits are exceeded, equipment can be either temporarily or permanently damaged.

Phase unbalance - electricity systems transfer alternative current using three phases, and to keep the correct operation of the grid, the charge that is connected to each of these phases should be approximately balanced. The most common way to assess phase unbalance is through the independent measurement of the voltage in each phase of the circuit, if the deviation from the average is larger than +/- 3%, the unbalance is considered unacceptable.

Line Limit Analysis

The image below shows the results of the line limit analysis. After conducting the year long power flow simulation, this figure shows the top ten most congested lines for each case defined. While Cases 0, 1 and 2 show a similar behaviour, there is a clear tendency to increase from Case 3 to Case 8. This is because the latter involve load increases (through the addition of EVs and HPs), which in turns uses a larger cable capacity in the main corridor of the grid. This suggests that for this feeder, the load (and not local generation) seems to be the limiting factor for line limits. Nonetheless, note how even in Case 8, where 100% of users have one EV and one HP installed, the greatest line congestion is not reaching 35% of the rated capacity, meaning that the grid is certainly able to host these resources, and potentially more.



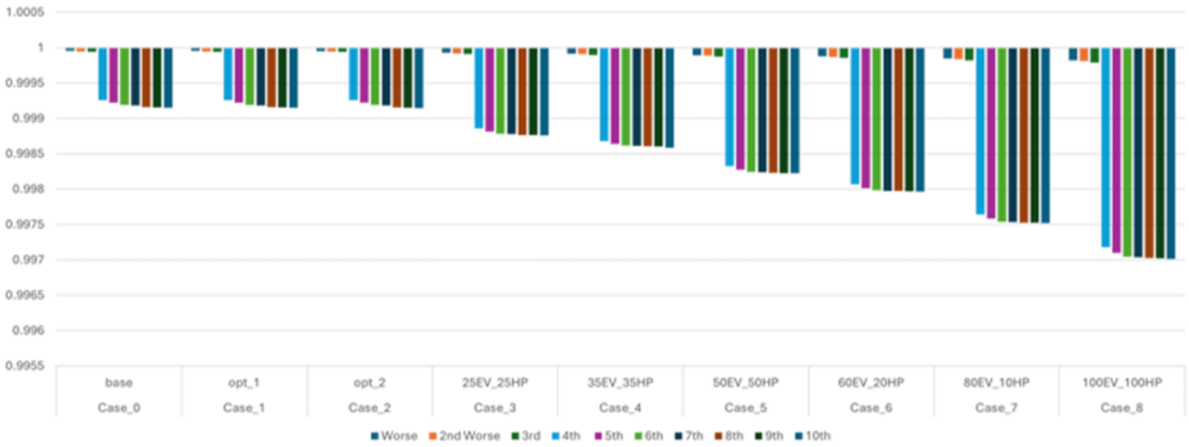
Maximum ampere capacity used in the cables – ten most congested lines in all cases studied [%]

The ten most congested lines are all located in the main corridor of the grid, close to the head of the feeder. This is coherent with the normal operation of radial distribution grids, where most Amperes (current) that enters or exits the grid, must follow this path.

Voltage Limit Analysis

Voltage issues are often a symptom of a network that is overloaded or that has too much local energy generation. This means that the results from the line-limit analysis should be reflected on voltage limits. Below are the results of two separate analysis for under- and over-voltage in the studied network.

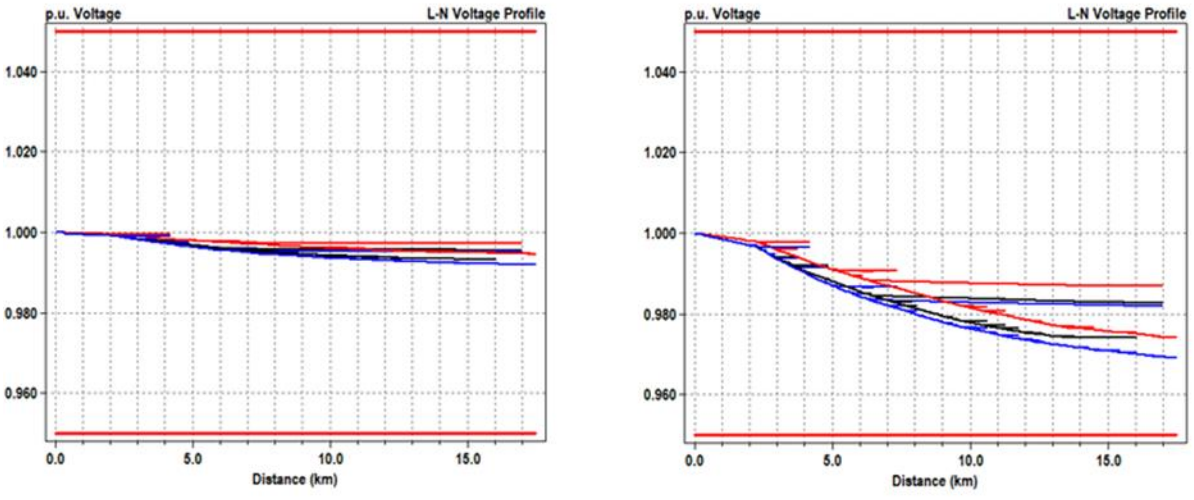
Under-Voltage Analysis - Low voltages come from voltage drop, a physical phenomenon produced when a current is transported using a cable. The larger the transported current, the larger the voltage drop will be. The figure below shows the effect of different scenarios on voltage decrease for the most affected 10 transformers. An immediate conclusion is a similar progression as the one seen in the line limit study: Cases 0, 1 and 2 having a similar behaviour because no additional load was included, while Cases 3 to 8 have larger voltage drops due to the addition of EVs and HPs. The maximum voltage drop seen is approximately 0.3%, which is not a concern considering that the limit given by the system operator is between 5-10%. This suggests that the grid is also within safety limits when considering these cases, in terms of undervoltage.



Over-Voltage Analysis - Over-voltages are associated with large amounts of local electricity generation, if a distributed generation installation is in the grid, an increase in voltage will be seen in places that are electrically neighbouring. As the project included the addition of significant PV generation, it was necessary to verify the effect this has on voltage increases. The figure below shows the ten largest over voltage issues for each case studied. Cases 0 and 1 show a negligible if not zero presence of voltage above the nominal value. This is expected because there is no PV in C0 and little in C1 installed in these scenarios. In contrast to the previous analysis, we see a progression of voltage increase from Cases 2 and 3, because those were the iterations in which PV generation was included. Ultimately, note that for cases 4 to 8 there is no significant evolution of overvoltage because even in the presence of more HPs and EVs, the amount of installed PV did not change significantly. With the largest increase in voltage at approximately 0.8%, these simulation results suggest that the scenarios proposed are well within parameters for overvoltage.

Unbalance Analysis

The power flow analysis allows for the independent evaluation of the three phases of the electrical system to estimate unbalances as defined in a previous section. For each three-phase bus of the system, the voltage in the phases A, B and C was estimated in each time-step. Results confirm that none of the scenarios creates problematic unbalances (i.e., above 3%). The figure below shows the voltage profiles of the network at the most critical voltage unbalance hours of the year, for the least concerning (i.e., 5th November, at 20:00 for case 0- Figure a) and the largest unbalance seen overall (i.e., 17th January, at 18:00 for case 8 – Figure b). In all cases, the values of unbalance are well below defined limits. This suggests that the implementation of ECs and their new resources in this network does not present a technical problem.



(a) (b)

Note in the figure above, that the presence of significant additional load creates additional voltage drop (e.g., a visibly lower curve when comparing Cases 0 and 8), and this additional voltage drop is coupled with a larger voltage unbalance. The maximum voltage unbalance estimated in the snapshot (a) for Case 0 is approximately 0.03%, while for Case 8 in the snapshot (b) is 1.02%. These results suggest that the additional loads from HPs and EVs is creating additional unbalance in the network, that even though are not problematic, should be surveyed or corrected.

Grid Capacity Analysis

Distribution grids are not isolated, but part of a much larger and complex system. Most electricity customers are connected to a LV network, that is then connected to a MV system (i.e., distribution), that is then connected to the national transmission network. There are complex interrelations between these different systems that are normally captured as “grid capacity”. When there is excess of generation (i.e., after local balancing), a distribution grid uses an “export capacity” to spill the excess to the upper, transmission grid. This is equivalent for local demand, for which the distribution grid uses an “import capacity”. These capacities are ultimately limited by infrastructure in the upper, transmission grid that is not known as part of the documentation.

The table below shows the maximum global imports and exports seen in the different cases.

	Maximum global imports		**Maximum global exports**	
Case study	**kWh**	**When ?**	**kWh**	**When ?**
Case 0	625.4116499	Nov 5, 20h	0	N/A
Case 1	625.4116499	Nov 5, 20h	0	N/A
Case 2	627.6815877	Nov 5, 20h	-194.4126583	Jun 10, 15h
Case 3	**922.3791368**	Nov 5, 20h	-601.9672917	Jun 11, 15h
Case 4	**1067.72733**	Jan 17, 18h	-603.8578887	Jun 11, 15h
Case 5	**1324.180558**	Jan 17, 18h	-603.4521166	Jun 11, 15h
Case 6	**1502.273097**	Jan 17, 18h	-601.8077537	Jun 11, 15h
Case 7	**1843.348175**	Jan 17, 18h	-602.093834	Jun 11, 15h
Case 8	**2179.847673**	Jan 17, 18h	-604.171433	Jun 11, 15h

While no information is available in the documentation for the E32 – Ballydavid network on the limits for transmission-level import and export capacity, we highlight that for cases 3 to 8, imports are larger than that of the base case. These larger imports are associated to new load from new EVs and HPs. To assess the viability of the scenarios, it is necessary to verify with the incumbent DSO if the export and import limits allow for the levels estimated in the simulation. This was done by using the Grid Capacity Heatmap developed by ESB Networks. Some transformers at different levels (i.e., LV, MV and transmission) have a reported installed capacity that can be used to contrast against demand and generation values from this study. Maximum exports and imports of the scenarios are within reported transformer installed capacities. The main substation of the Dingle peninsula is rated at 5 MVA, which is enough to supply for the maximum imports registered in the table above (i.e., 2.1 MVA). However, it is important to note that this substation serves another three feeders (i.e., the 5 MVAs are shared with other feeders). It is recommended to perform a similar study to determine if this substation's installed capacity is enough for all.

15 Project Outputs

The following is a synopsis of the various outputs of the project which align with the Milestones set out at the beginning of the operation.

Architecture Design - An Architecture structure was developed to cater for all the actors in a potential EC. The design allows all elements from the Substation to its Feeder lines, Branches, Transformers, Site Meters and any Devices that may be connected to it be represented. These devices may be batteries, solar panels, electric vehicles or heat pumps. The Architecture allows for members to join and/or leave the EC, add/delete devices and it can be expanded exponentially along the geographic network.

Network Strategy - A Network Strategy was developed which caters for exactly how the electricity grid is outlined in a particular area. As energy sharing is based on being connected to other EC members, it is critical the strategy conforms with the relationship between the members. It also must cater for what level of 'Devices' can be integrated at any point in the network. Details of the sizes and capacities of all the elements is included from the substation down to the meters which dictates the size and amount of devices, such as solar panels, that can be integrated at any point on the network.

Energy Flow Strategy - An Energy Flow Strategy was developed to cater for how energy will be shared within an EC when it is available. The Architecture and Network Strategies above cater for how the system handles all devices and elements within an EC. This strategy applies a Tree Structure to each element by giving a 'Weighting' to each position. This dictates the relationship that each element has based on where the energy flows when it is available. From the diagram below, the system knows that when a transformer has sufficient energy for the metres beneath it that it will 'spill' energy downstream to the next point in the tree according to the weighting. This strategy is replicated when energy is spilled from a branch downstream to the next branch along the feeder.

Energy Models - Load models for the micro-EC's and the various feeders were completed using the CREST model and other data sources. These were aggregated together to data available from ESBN and other sources and compared. Results were validated for accuracy levels.

EC Elements – All elements of the EC were modelled including Solar generation, Battery Charge/Discharge models, Prediction and Optimisation Modelling and Smart Grid techniques.

Platform – The software platform developed presents a geographic map with an accurate representation of the local network overlaid with the details of load profiles and the number and type of meters at each node. This enables the end user to create EC's at any point on the network and create specific Sustainability reports. It encapsulates all the functionality developed for the project and facilitates various scenarios to be built by amending the criteria and assessing the effect on results.

Electrical Modelling – Along with external experts in the field, a detailed Electrical Model of the Dingle network to assess the effect on Voltage change, Line loading, Unbalance and Grid Capacity with the various EC sizes and mix of criteria.

Dissemination – A project page was designed and developed for the Walton website early in the operation which outlines an overview of the project and its goals. Aspects such as Benefit to society, State of the Art and Limitations and the Research Challenge were outlined in detail. Its novel approach to solving the regions problem and the potential impact were discussed. The input and links to other projects were outlined and how this project will build on that knowledge. Finally, the strategy of how the project will be implemented and how it will deliver the Key Objectives were outlined. A link to the site is included below.

https://waltoninstitute.ie/projects/sustainability-dingle

There were two major Dissemination events that took place over the course of the project. A Stakeholder Event was held in Dingle to outline the objectives to a range of people across the industry early in the project. It was outlined how local businesses and individuals can learn how REC's can enable renewable energy technologies to be integrated and maximise their self-sustainability.

Secondly, a Final Project Event was held to outline the results and findings at the end of the project. A broad overview of the objectives of the project and how Energy Communities can play a significant role in decarbonising the energy sector was outlined. A demonstration of the software platform and how you can design an EC on the existing network in the Dingle area and sustainably balance it with renewable energy, batteries and smart grid techniques. The event was concluded with the very positive project results including an analysis of electrifying heat and transport as well as the electrical aspects of balancing the network on voltage and line loads.

There was significant PR around the awarding of the project and both events. It was covered on websites, social media channels, national radio Raidio na Gaeltachta and local media in Kerry.

The project team also had regular and in depth engagement with industry stakeholders such as ESB Networks, DECC, CRU and SEAI which had positive impact on the project and its results. All local stakeholders were also engaged with including UnG, Dingle Hub, local SEC's and the West Kerry dairy group.

Milestones - Reviewing the project milestones as set out from the Project Objectives, all were clearly met adding impact to the project. The full list of milestones are included below.

Micro level dataset for initial local Energy Community
Dataset of all energy elements for the Dingle region
Modelling of small energy community
Extension of models to broader community
Analysis of non-electrical energy demand
Modelling of migration of non-electrical demand to electrical
Sustainability Report for the Dingle Region
Report Launch Event
Stakeholder Events
Issue Best Practice Guide
All Deliverables and Objectives achieved.

16 Conclusion

For the Clean Energy Transition and to decarbonise our energy system, we need to make the grid smarter. To integrate more Renewable Energy, which are variable and intermittent by their nature, we need Smart Grid Technologies, particularly at a local, distributed level at the site of consumption. Renewable Energy Communities can play a significant role by balancing Supply & Demand and maximising Self-Sustainability. This project has outlined the role EC's can play in the Clean Energy Transition. The various elements that constitute EC's were outlined in detail and the role they play in the process.

Significant data was acquired from multiple sources which enabled us to expand the 2 micro-EC's in Ballinaboula and Milltown across the region and assess their impact on Sustainability levels. The Network data acquired allowed us to map load profiles for small clusters behind a single transformer and build that up to the transformers and loads adjacent to them. This was then expanded to branch and feeder level which informed the strategy to roll this out regionally.

Modelling techniques such as CREST proved impactful in modelling energy profiles for non-metered residential load data. This enabled us to simulate residential load profiles for the range of house types in the area. For the micro-EC's, the number of residences in the immediate area of the clusters was aggregated to the factory and office data to give a total load for these EC's.

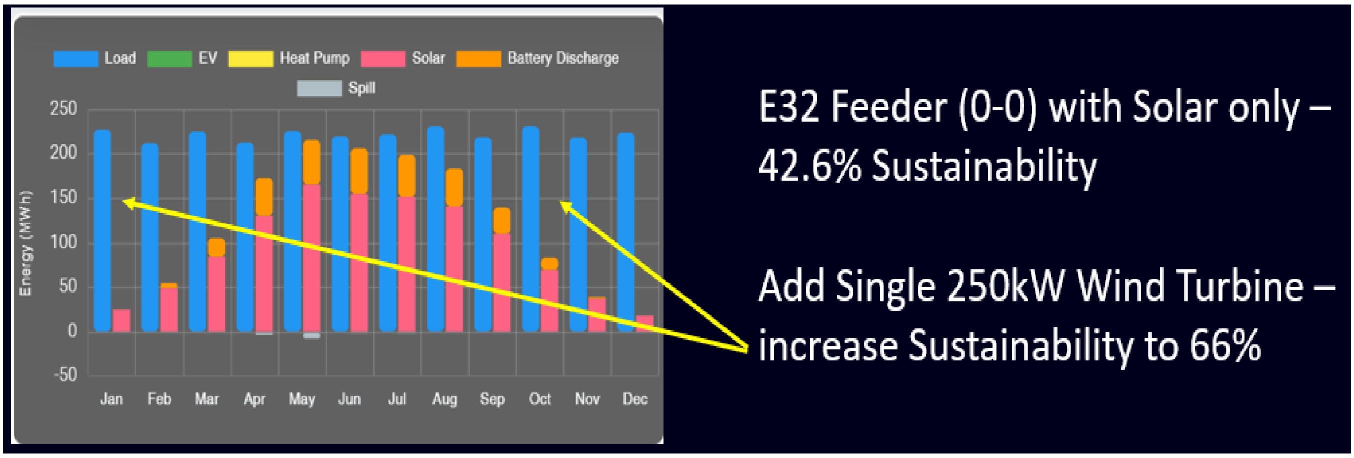
The network datasets acquired were used to develop models of the peninsula's electrical load profile. This data is also geographically specific and allowed us to relate to the actual power flow of the grid network. Renewable energy models were then used along with battery systems to balance supply and demand and maximise the self-sustainability of EC's. Heat and Transport models were also secured and, as these elements are electrified, we can alter the models accordingly and increase the level of renewables to match the increased electrical demand.

From the Dingle EMP, Heat and Transport are the largest sectors for energy consumption on the peninsula. As these must be electrified in the future, we acquired datasets from previous studies with applicable criteria to the Dingle peninsula. This enabled us to apply HP and EV penetration levels to each meter and amend the load profiles of potential EC's. Generally, adding HP and EV profiles to an EC reduces its Sustainability when only using solar as a renewable energy source as the extra load is mostly night based. This extra demand has a significant impact on the load profiles – for the E32 feeder, the current demand is 2.67GWh annually which would increase to 5.97GWh were every household on the feeder to implement HP technology and have one EV. This is more than a 2-fold increase and the network would need significant investment and reinforcement to accommodate it. The analysis would suggest that increasing levels of demand on the system, such as electrifying heat and transport, will be difficult without renewable energy integration within local EC's.

However, as we can see from the Electrical Analysis section, significant loads can be added to the existing network when balanced with local renewable energy generation. The analysis shows that voltage change (positive and negative), line loading, unbalance and grid capacity are all maintained within limits on the existing network when this 2 fold expansion is balanced using EC concepts. The E32 feeder is a robust network, but nonetheless, this demonstrates what can be achieved with existing assets by implementing smart grid techniques and EC concepts on the traditional grid.

Sustainability levels of potential EC’s for numerous scenarios were demonstrated. We saw how the load profiles change from EC’s that may be predominantly residential versus industrial/commercial and the ability of solar energy to match them. Sustainability levels of the Ballinaboula EC, which is predominantly industrial, scored 30.2% and when we expanded this out across the full E32 feeder, this improved to 42.6%. This is due to residential loads being a better fit with solar profiles. The level of MEC that is applied to an EC will also have a significant impact on its sustainability. Relatively conservative levels were used in the scenarios to make the results as realistic as possible.

Wind energy is a proven technology, and its profile can be complimentary to solar in maximising a regions sustainability. Although the peninsula is considered a no-go for wind projects, there are areas where the technology could be sensitively located, and a blanket policy does not serve the region well. Hybrid projects with battery could be strategically placed with sensitivity. The graphic below shows how little solar is contributing to the sustainability levels in wintertime and by analysing the data and bringing in typical wind turbine data, we could easily increase the sustainability on the E32 feeder from 42.6% to 66% by incorporating a relatively small 250kW wind turbine into this EC.



E32 Feeder (0-0) with Solar only – 42.6% Sustainability

Add Single 250kW Wind Turbine – increase Sustainability to 66%

The energy mix of an EC is a critical component and may be more applicable to EC’s based in less sensitive areas. Hydrogen and Ocean projects are potentially some way off until the scale of the technology, price points and regulation aspects progress. However, they have the potential to play a significant role in the future.

The Dingle region, being coastal, can potentially avail of all of these technologies. However, solar is the only one that has any applications currently in the Dingle region and it is currently of a minimal scale. Being a rural location, energy profiles are small and disbursed and EC’s could be a mechanism to organise the population into groups that could partake. As many individuals do not have the energy profile or wherewithal to integrate their own renewable energy, as part of an EC, they can aggregate their resources and partake in the market. Similarly, individuals are too small to operate in other areas such as the upcoming Flexibility market, but can do so as part of a larger EC.

The potential for how EC's can play a significant role in the clean energy transition has been clearly demonstrated if the EU Directives are transposed effectively. As this is a significant change to how the distribution system may work, we have outlined how other mechanisms could be deployed in the interim as progressive steps towards full EC implementation. Mechanisms from the Installed Capacity Cap decision paper could be deployed as to the rules that the EC would have to conform to with the DSO to ensure capacity levels are maintained for the wider grid. The EC could be a hybrid site with a mix of solar, wind and battery that can share its MEC with the ability to have Multiple Legal Entities behind a single connection point. Export Limiting Systems and reverse relays can be deployed on the DSO side to ensure the Optimisation systems never export more than the capacity limits set for them.

The role of the DSO across the EU in the progression of EC's is evident from the analysis. Data from smart metering systems is managed by the respective DSO's in EU jurisdictions and they play a central role in enabling the flow of energy and settling the financial transactions based on that countries rules. ESB Networks will need to play a similar role in Ireland for EC's to reach their potential. Mechanisms to ensure the network resiliency, capacity level requirements and voltage balancing levels can be incorporated.

Trials and pilots can be integrated at the micro-EC level as demonstrated and with the appropriate monitoring equipment on the network, the effects on the local grid can be accurately measured. The initial pilot could be in a single building where any changes to the network would be within the curtilage of a single landowner. Moving beyond the single building scenario, the next potential cohort for an EC could be a campus environment where multiple buildings are located on a single site connected on the same electrical network feeder and substation. This could be a hospital site, university, port, airport or industrial estate under single ownership. Same principles could be deployed over a wider geographic area. Once these principles are proven, it should pave the way for full P2P energy sharing and EC deployment.

Finally, SETU would like to thank everyone who contributed to the project including funders, the Sustainable Energy Authority of Ireland, Údarás na Gaeltachta as partners and Mol Teic t/a Dingle Creativity and Innovation Hub and Corca Dhuibhne Community Energy who served as collaborators on the project. Other stakeholders such as ESB Networks, UCC and the West Kerry Dairy SEC who provided datasets and project outputs were of invaluable assistance.

17 Acknowledgement

This deliverable - Final Management Report has been funded by the Sustainable Energy Authority of Ireland under the SEAI Research, Development & Demonstration Funding Programme 2021, Grant number 21/RDD/763

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