Sustainable Energy Authority of Ireland

National Energy Research, Development & Demonstration Funding Programme

FINAL REPORT

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

SECTION 1: PROJECT DETAILS

Project Title	Sustainability Dingle
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Report Submission Date	31/7/2024

	Name	**Organisation**
Project Partner(s)	Fionnán Ó hOgáin	Údarás na Gaeltachta
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Project Summary (max 500 words)

Sustainability Dingle enables Energy Communities (EC's) to take control of their energy profiles and become prosumers to play a central role in 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 trading, Demand Side Management, Load Shifting and Battery Storage. To enable this, we acquired and analysed energy data and developed models to maximise energy elements against mechanisms for Energy Communities and Renewable energy integration in line with these EU Directives.

A software platform was developed that encapsulates all of the functionality required for an EC Load profiles were developed for every end user group and these points were geographically mapped on to the location of every meter and transformer in Dingle. This enables 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. Scenarios for when heat and transport were also included.

Multiple EC's were designed on the platform starting with smaller branches and then expanding the EC out along a feeder until the entire feeder is included. This resulted in varying sustainability scores - the mainly Industrial area of Ballinaboula gave a sustainability score of 30.2% with a low penetration of heat pumps and EV's. As this EC is expanded out along the entire E32 feeder, it results in a total annual load of 2,670MWh with 1.2MW of solar and 4.1MWh of battery distributed along the network, increasing the sustainability score to 42.6%. As heat and transport are electrified, we found these loads to be mainly night based which is a poor fit with solar and the score across the E32 feeder reduces to 20.3% when the penetration of both is increased to 100%, giving a total annual load of 5,970 MWh. An electrical analysis was also included and interestingly, the current E32 feeder has the capacity to fully electrify heat and transport when matched with balancing renewable energy.

Finally, the compilation of an extensive project report outlines how a coastal community, such as Dingle, can build a Sustainability model for Local Energy Communities and its wider region and contribute to the Clean Energy Transition.

Keywords (min 3 and max 10)	Sustainability; Energy Communities; Energy Sharing; Clean Energy Transition; Distributed Renewable Energy; Smart Grid

SECTION 2: FINAL TECHNICAL REPORT (max 10 pages)

2.1 Executive Summary

The Sustainability Dingle project ran from March 2022 to May 2024 and 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 and provide 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 EC concepts as these micro-EC's are rolled out geographically and expanded along the network across the region. 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 fed into our analysis.

This Final Project Report covers all aspects of an EC and how the data to feed the models was acquired, analysed and mined to provide an accurate picture of the load profiles on the network and its operation. We 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.

2.2 Introduction to Project

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. EC's consist of a large number of elements and the project focussed on the areas below which were all represented in the Sustainability Dingle Software Platform;

Energy Markets - 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 EC's and participate in the market and potentially become price makers as opposed to price takers.
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, 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 section 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.

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 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 (REC'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. 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.

The key to all concepts from the Directives 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.

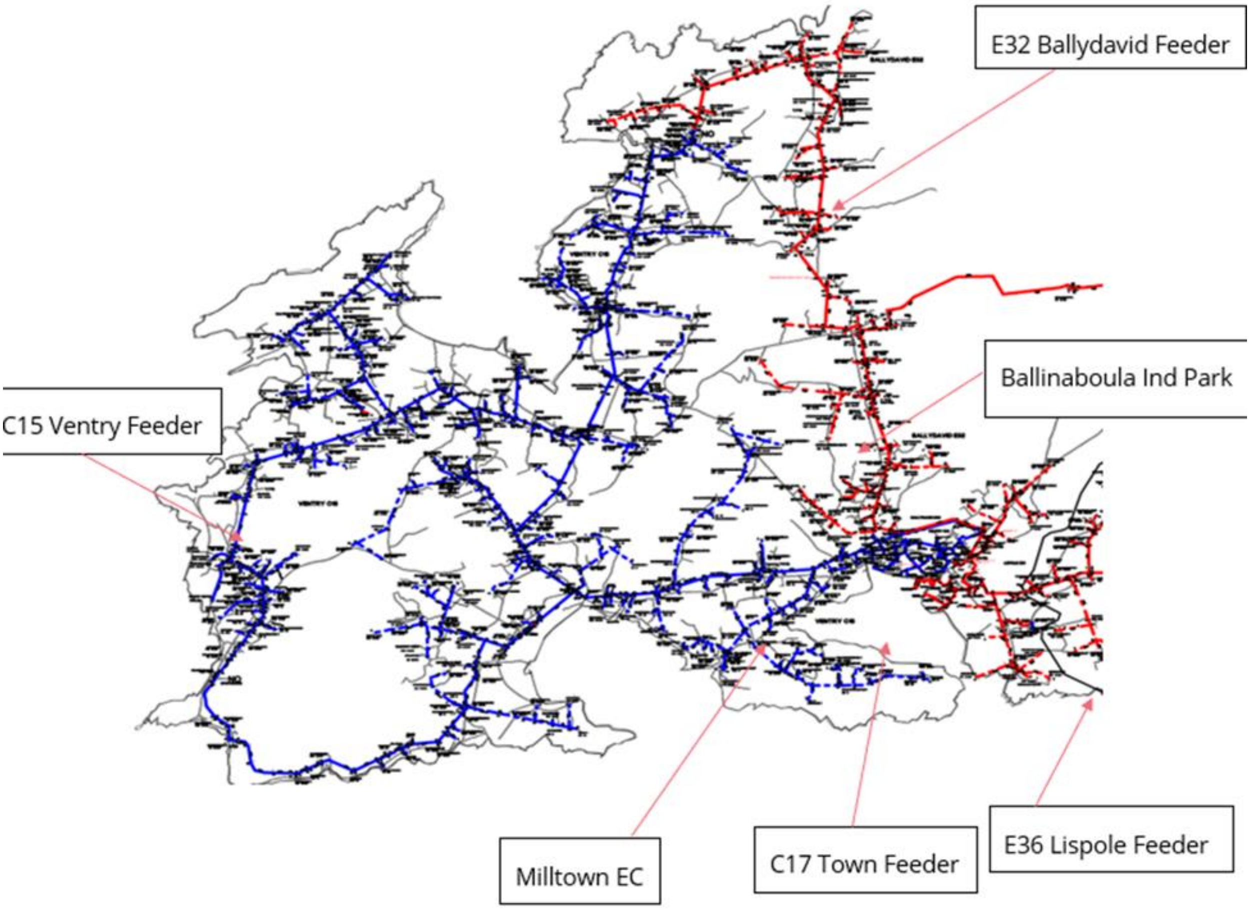
Energy Communities - Although the EU Directives outlined above have been passed for some time, Ireland is still in the consultation phase of transposing these into national law. Government bodies such as the Regulator (CRU) and the Energy Department (DECC) have issued various consultations around Active 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.

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 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).

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. 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. 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.

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 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.

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.

Load Data & Models - The Dingle Hub, as collaborators on the project, commissioned the production of an Energy Master Plan (EMP) for the Peninsula to understand the community's current energy consumption. This 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 due to its isolated nature and the economic activity of the region is highly dependent on tourism, farming and fishing. It also breaks down the usage across the energy vectors of Electricity, Heat and Transport. This gave us high level data across the peninsula to validate against our models.

From an Electricity perspective, Residential loads in the area are predominant. 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. 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.

The project already had granular data for Commercial and Industrial premises from the RegEnergy project and were able to incorporate these into our models. Agriculture is a large sector in the area and the team engaged with the West Kerry Dairy Farmers Sustainable Energy Community who also commissioned an Energy Master Plan. They supplied their energy profiles enabling us to incorporate this sector into our models. 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). 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.

Energy Community Elements - From Section 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.

Renewable energy - As the Dingle peninsula is designated as a scenic area it would be very difficult to integrate wind turbines, so we have focused solely on solar energy for this area. We now need solar energy data such that the system can be designed to maximise its self-sustainability. 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 users 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. 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. Other parameters include Pressure, Temperature, Wind speed and direction, Solar azimuth and elevation, PV array type, *azimuth,* tilt angle, efficiency and losses.

Battery – 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.

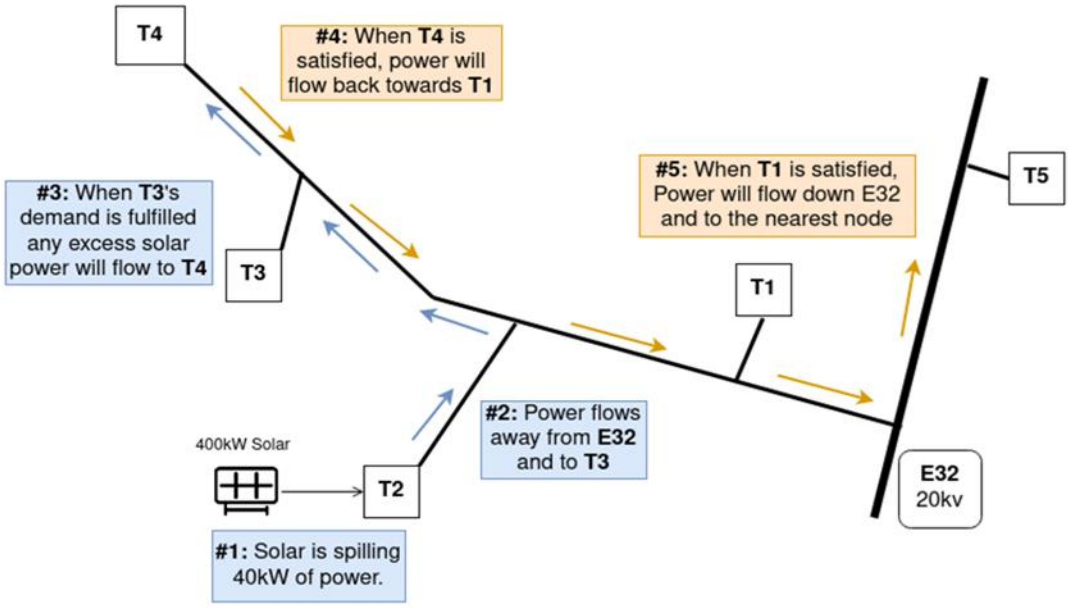
Smart Grid Control Systems – A major component of integrating these renewable energy sources onto the grid is the ability to forecast their output such that it can be matched effectively with demand, second by second. Renewable energy forecasting is a rapidly evolving field and there is a continuous 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 - by aggregating the demand profile of all members of an EC it is much easier to design a renewable energy system to match. 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.

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. The strategy for the development of the Sustainability Dingle software platform requires an architecture to apply the modelling system of all elements of the EC and map them with the network data. This is a system of layers from the substation, feeders, branches, transformers down to individual load sites such as factories, houses and shops. 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. 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.

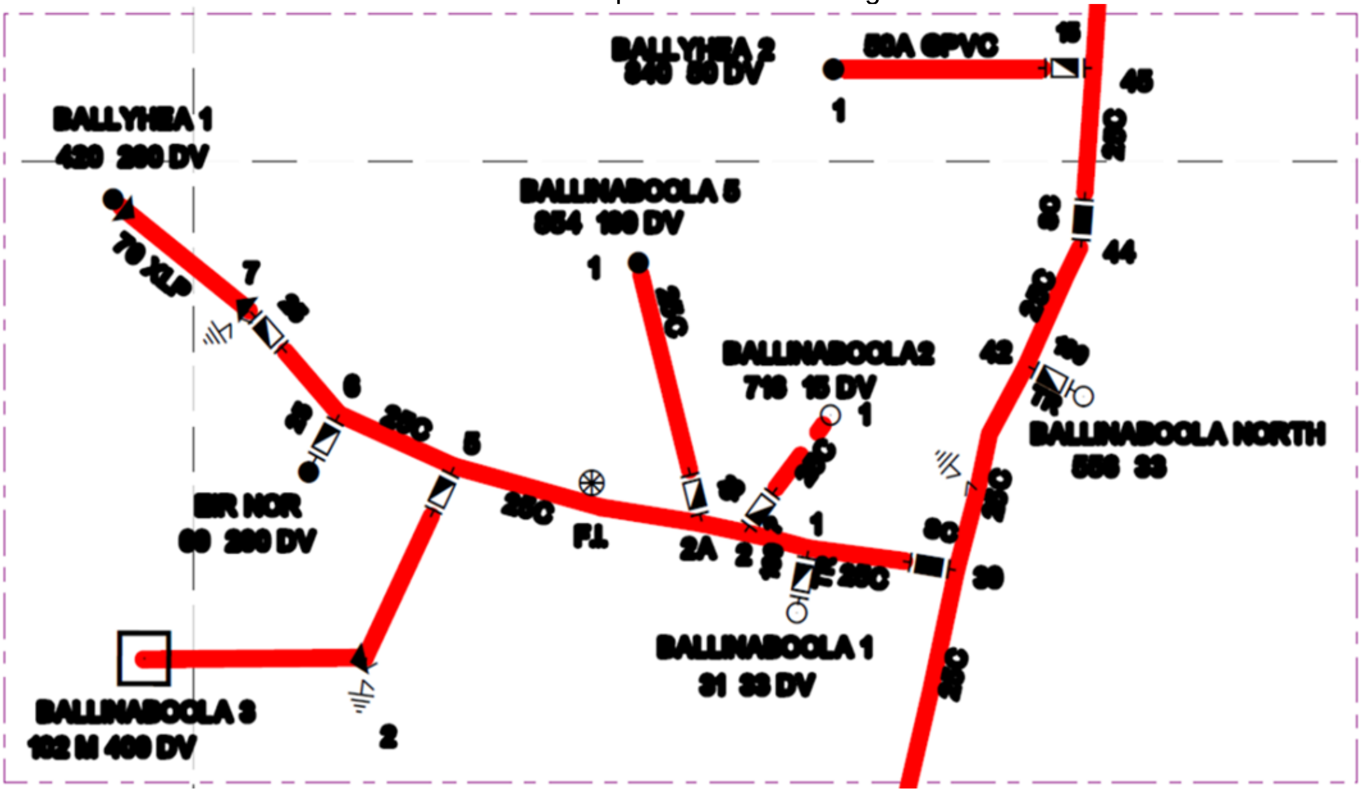
An Energy Flow Strategy was then developed to cater for how energy will be shared within an EC when it is available. Substations, feeders, transformers and site meters are all physical elements and have a naming structure within the ESBN system. During the design of this project, the team introduced the concept of a 'Branch' as we are focused on creating EC's with entities who are electrically close to each other. Branches are fed from the main feeder line to provide electricity to entities in that area and 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.



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.

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 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.

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.



The software platform then generates an aggregated energy demand profile across all the DG meters behind each transformer for every hour of the year. 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.

From a Solar perspective, we use the PV Watts system to generate a model for the requisite install across an EC. We need to assess the local characteristics and 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 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 probability factors applied accordingly. 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.

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.

The team acquired datasets for both Heat and Transport from previous studies with applicability criteria to the Dingle peninsula which enabled 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.

2.3 Project Objectives

Section 2.2 above outlines the detail of the project and how the various elements were developed which culminated in all objectives being achieved. Ultimately, these aspects were all represented in the Sustainability Dingle software platform which enables the user to design and create EC’s and assess the effect of modifying each element on its sustainability. The table below outlines the objectives as set out in the proposal and from the detail above, it is clear all were achieved during the project.

No:	Objective Description:	Delivery Timeline (in Months):
1.	Acquire and analyse accurate energy data for the region segregated across all elements	Month 12
2.	Develop a Model to maximise all energy elements against mechanisms for Energy Communities and Renewable energy integration in line with the new EU Directives.	Month 20
3.	Compile report to outline a Sustainability model for Local Energy Communities and the wider region	Month 22
4.	Implement a Communications strategy such that the outputs and results are disseminated to all stakeholders and the wider public.	Month 24
5.	Develop a Best Practice Guide on developing the structures of setting up a legal Energy Community Group	Month 24

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 is included below which were all met in a timely manner.

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.

2.4 Summary of Key Findings/Outcomes

- Innovation 1: 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.

- Innovation 2: Modelling Techniques

There is a myriad of energy users connected to the grid. These range from public lighting to residential houses, farms, small businesses, commercial offices, retail and industry. ESB Networks group these customers into DG sectors. The team have used modelling techniques such as the CREST model to develop hourly profiles and factor them to suit the higher level data existing for the local Dingle area. Having access to the location of the DG meter types allows us to develop hyper local profiles for every transformer. Therefore, when developing an EC, we can aggregate the members that are connected to each other. Similarly, we have used existing solar generation data for the area based on location, panel tilt, azimuth and other criteria to model the outputs of various systems over every hour of a year.

- Innovation 3: Network Representation

An electrical network can resemble a spider's web in its complexity. Relational databases were employed to store the network data in a manner which is an intuitive way of representing all data in tables as well as their relationship from an electrical connectivity viewpoint. This model enables us to implement rules as to who can physically share energy with each other. It results in a tree structure where the physical flow of electricity can be modelled when one area of an EC has excess energy at any point in time and can share with someone with demand.

- Innovation 4: 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. The system then knows 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.

- Innovation 5: Optimisation Mechanisms

Once an EC is designed, a load profile is created from the aggregate of its members. Optimisation techniques are then employed to integrate the optimum level of solar energy and battery systems to maximise sustainability. Rules around local grid capacity and spill levels are incorporated in the calculations.

- Innovation 6: Heat & Transport Models

Datasets for both Heat and Transport from previous studies were acquired with applicability criteria to the Dingle peninsula which enabled us to build scenarios as these sectors are electrified. 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.

- Innovation 7: Sustainability Dingle Software Platform

A software platform that encapsulates all of the functionality required and enables 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.

- Innovation 8: Electrical Capacity Analysis

An assessment of the practical implementation of EC's was conducted via an analysis of the Electrical Capacity of the Dingle network. To facilitate the radical increase in distributed generation, we showed the existing network can accommodate this change as well as the electrification of Heat and Transport without adverse effects on voltage change, line loadings, unbalance and capacity.

2.5 Project Impact

Clearly position the impact of your project with reference to the needs of the Irish Energy Sector, national and international policy objectives, and SEAI's remit.
Discuss the key impacts of your project: societal, economic, technological or otherwise. Clearly identify and highlight the value of your project in the wider context.

With the "Clean Energy for all Europeans" package (Clean Energy Package), the EU introduced new provisions on the energy market design and frameworks for new energy initiatives. Specifically, the recasts of the Renewable Energy Directive (REDII) and the Electricity Market Directive (EMDII) provide basic definitions and requirements for the activities of individual and collective self-consumption within Renewable Energy Communities. 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. 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.

This project has demonstrated the positive effects EC's can have on local communities and how they can be a significant driver in the Clean Energy Transition. The results from the Dingle area can be transposed to any network in the country to facilitate EC's to integrate renewable technologies at a local level and sweat the assets of the existing network. The project outlined how some initiatives such as Private Wires & Networks and the relaxation of the Installed Capacity Cap can be stepping stones to full EC implementation.

The project also completed an analysis of the transposition process in other EU jurisdictions and found significant progress in Portugal, Spain, Italy, France and Austria where EC's are now flourishing and the accruing benefits are clear.

The most significant impact of the project was the design and build of a software platform that encapsulates all of the functionality required to 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 data of the local network was acquired, enabling the deployment of an accurate representation of the network and transposed geographically on a map of the Dingle region. The end user can then select a branch on the network to create an EC and the system will build an energy load model of all of the meters within it. Branches can be added to the EC as you roll it out geographically along the network until an entire feeder is complete. The system will then design the requisite level of solar and battery systems to maximise the sustainability of the EC. Models were also included to incorporate the electrification of heat and transport and their effect on the EC. The graphic below shows a snapshot of a particular EC and 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.

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BnB 2

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

As the EU Directives are not yet law in Ireland, it is difficult to quantitatively assess the societal and economic impacts of EC's but the project proves their efficacy and developments across the EU show their positive outcomes.

2.6 Recommendations

The project has demonstrated the substantial advantages that EC's can bring to local communities and to the wider grid and the role they can play in reaching our national climate targets. The software platform is a tool that enables end users, from local communities to policy makers, to build scenarios and analyse the effects of varying the make up of the different elements of an EC on its sustainability.

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.

This project would strongly recommend that the various stakeholders in Ireland – ESBN, CRU, DECC and SEAI – would convene workshops with Industry and academia to progress the aspects required to enable the advantages EC's can bring. This should lead to Pilots, similar to the EC’s developed in this project, to prove and test the various aspects of sustainable EC’s. The results from these trials can then inform the regulators and legislators with real data such that the EU Directives can be transposed into law to bring maximum effect.

2.7 Conclusions and Next Steps

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.

Accurate data was essential in creating the models that were applicable and realistic to the local environment. Marrying load models with network data results in accurate profiles across every hour of the year enabled the team to design renewable and storage technologies along with smart grid techniques to maximise sustainability.

Multiple EC’s were designed on the platform resulting in varying sustainability scores. The mainly Industrial area of Ballinaboula gave a sustainability score of 30.2% with a low penetration of heat pumps and EV’s. As this EC is expanded out along the entire E32 feeder, it results in a total annual load of 2,670MWh with 1.2MW of solar and 4.1MWh of battery distributed along the network, increasing the sustainability score to 42.6%. The remainder of the E32 feeder is mainly residential and proved to be a good mix with the industrial loads and facilitated substantial integration of solar. As heat and transport are electrified, we found these loads to be mainly night based which is a poor fit with solar and the score across the E32 feeder reduces to 20.3% when the penetration of both is increased to 100%, giving a total annual load of 5,970 MWh.

Merging all 3 feeders E32, C15 and C17, supplying electricity to all the peninsula from Dingle town out, has a load profile of 18,000MWh with no HP or EV penetration increasing to 38,880MWh with 100% penetration of each. Sustainability decreases from 28.4% to 13.1% as heat and transport are fully electrified.

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 and the potential effect on voltage change, line loadings, etc. The analysis found that 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, even when we reach 100% penetration of heat and transport on the E32 feeder. This 2-fold expansion in demand would need significant investment in the network without balancing supply and demand 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.

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. Solar contributes very little 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 wind turbine into this EC. We have seen above that electrifying heat and transport is a poor fit with solar profiles but wind can be a good fit meeting night and winter loads. The energy mix of an EC is a critical component and may be more applicable to EC's based in less sensitive areas and analysis of other regions which may accommodate a wider array of energy sources would be a logical next step.