EXPLORING SUSTAINABLE ENERGY OPTIONS FOR LOOP HEAD

Europa-Universität Flensburg

IC 2021

ACKNOWLEDGEMENT

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Kick off meeting of Digital EEM International Class 2021

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AD	Anaerobic Digester
BEH	Better Energy Homes
BER	Building Energy Rate
CAPEX	CAPital EXpenditure
CAT	Clare Accessible Transport
COD	Chemical Oxygen Demand
CSO	Central Statistics Office
EUF	Europa Universität Felnsburg
GHG	Green House Gas
HDD	Heating Degree Days
IC	International Class
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
LCOE	Levelized Cost of Electricity
LEAP	Loop Head Energy Action Partnership
LED	Light Emitting Diodes
NPV	Net Present Value
OPEX	Operating Expenses
PV	Photo Voltaic
RE	Renewable Energy
RNG	Renewable Natural Gas
SEAI	Sustainable Energy Authority of Ireland
SEC	Sustainable Energy Community
VAT	Value Added Tax

EXECUTIVE SUMMARY

Community energy planning provides a high degree of ownership and control to a community aiding towards the development of a sustainable energy sector. Community engagement is a crucial aspect of the energy planning process. Thus, the following study conducted by the international class 2021 emphasized on involving and interacting with the local community of the peninsula to get a better understanding of their perspective of the energy sector and their preferences, on which this study is based. Also, inputs were taken from the previous study of IC 2020 to consolidate the working sectors of residential, farming, energy modelling and community energy training.

The students working in the residential sector focused on energy efficiency measures in buildings and their effect on energy consumption in residential sector. The report provides insight on composition of heat consumption in Loop Head and effect of energy efficient interventions towards cost savings. A BER estimator tool was developed to provide recommendations on improving energy efficiency for an individual household based on the pre-existing conditions of the household. The study also identified several factors which influence the heat demand in residential sector and the retrofitting measures to reduce heat demand and heat losses in buildings. The results of the case study showed the implementation of retrofitting measures and installation of air-to-air heat pumps had potential with regards to cost savings. The cheapest option for the heating technology was identified as biomass boiler with investment cost of about 5,000 Euros with cost savings of 2,675 Euros per annum. The cheapest heat pump option of 11,790 Euros were identified with 3,241 Euros of annual reduction in expenditure.

The students introduced the farming sector to the concept of a circular economy and identified possible areas of intervention of the concept in the sector. Three main working areas were identified to implement circularity in individual farms. First, energy efficiency measures were identified and potential improvement measures for the farms were recommended. Secondly to meet the energy self-sufficiency solar PV systems were investigated. An open interactive solar technical design and financial estimation tool was developed. Finally, to address the issues of waste management in the farms the anaerobic digestion technology was analysed, and a similar

interactive tool was developed. Running simulations of the tools on sample farm inputs showed good technical and financial feasibility of solar PV systems thus ensuring potential for self-energy generation. The results form the AD tool showed potential with regards to technical feasibility and waste management but did show attractive financial feasibility in the absence of financial incentives.

To promote and assist in the establishment process of Sustainable energy system, an excel energy modelling tool was developed for Loop Head. This tool will provide the basis for investment decisions, support operational decisions, and perform scenario analysis. It is designed to assist the potential users from Loop Head to analyse overall system performance. Besides, the model is also designed to aid the users to identify solutions for obtaining energy efficiency in residential buildings and attain sustainability in Loop Head Farms.

In addition, community capacity building workshops were conducted through the LEAP Energy Academy to inform the community members of the work of IC2021, and to get their feedback as the work is being done. The workshops allowed IC2021 to familiarize with relevant concepts and terminologies in community energy with focus on Loop Head. Speakers from Scottish communities, whom in the past hosted international class we also invited to share experiences with the Loop Head community. Since this year’s international class is virtual, the workshops also allowed the Flensburg students to interact with the Loop Head community.

1. Background

1.1. Community Energy Planning

Community energy provides ‘Power to the people’. (Seyfang et al., 2013) defined community energy as “those projects where communities (of place or interest) exhibit a high degree of ownership and control, as well as benefiting collectively from the outcomes, and we include both supply- and demand-side sustainable energy initiatives”. The idea is simple, communities generate energy in the community to be consumed by the community, but how it is done depends on local and national legislation/ regulations at the time. In Europe, Community energy refers to projects where citizens own or participate, form a legal structure to collectively finance and establish energy projects, to generate electricity, heat from renewable energy projects (Claudia Fruhmann and Nina Knittel, 2016). Renewable energy generated by such projects is collectively sold, to members of community, and local energy utilities, and the profit is split among the participating members.

The two approaches of community energy projects are: the bottom-up approach; where citizens establish and own renewable energy projects, and top-down approach; citizens participation is realized through buying shares of renewable energy projects of already established or planned energy projects. The latter approach allows renewable energy projects to be co-owned by citizens, thus facilitating large-scale projects.

While there does not exist a magna carta for community energy planning, which has seen diverse processes in different parts of the world, the importance of community involvement is never understated. Findings by (Heaslip et al., 2016) indicate that, despite a lack of a specific implementation framework, the tools and methodologies used by the sustainable energy communities they studied were similar. (Heaslip et al., 2016)’s research studied the sustainable energy journeys of Marstal and Samsø in Denmark and Cloughjordan in Ireland. Their research also found that the Sustainable Energy Communities (SECs) studied were financially motivated, looking to bolster local economy and reduce energy cost. In addition to that (Seyfang et al., 2013) found that saving money on energy bills is the single most cited objective for SECs in the UK.

Other objectives included: reducing carbon emissions, community empowerment, improve local environment and influence sustainability and climate change policy. Information and incentives from larger organizations is also cited by a number of communities studied by (St. Denis and Parker, 2009) in Canada.

One of the most important characteristics of community-owned (or co-owned) energy projects is the active participation of citizens in renewable energy generation, thus, significantly increasing the public acceptance of renewable energy production. This is because community-owned renewable energy projects provide co-benefits to the participants by harnessing local natural resources, building social capital, counteracting on fuel poverty and increasing employment in regional level (Claudia Fruhmann and Nina Knittel, 2016). These close ties to the community increase public awareness, decrease local opposition to renewable energy projects and support the transition to low carbon energy.

Due to their heavy financial commitments and the relatively low risk-return ratios of Renewable Energy (RE) projects, established energy companies are locked into fossil fuel-based infrastructures (Lowitzsch, 2018). On the other hand, community ownership generally operates with small capacities despite relatively high capital costs per kW of installed power compared to large central plant and does not have to worry much about their quarterly returns as well. This approach is changing energy supply infrastructure in many countries and driving the energy transition with small-scale Renewable Energy Technologies (RETs) (Lowitzsch, 2018).

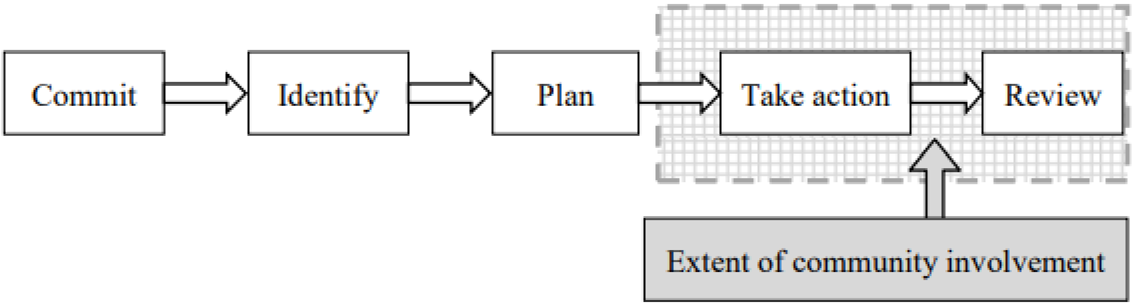
1.2. Community Energy in Ireland

In Ireland, the Energy White Paper launched in 2015 attaches a lot of weight to communities' contributions to achieving a low carbon energy system by 2050. According to SEAI, there are over 400 communities which are working together in the sustainable energy network (SEAI, 2021c). The common goals of these sustainable energy communities are energy-efficiency, use renewable energy, and consider smart energy solutions. The activities of these communities are related to:

- Improving Sustainability and environment by changing energy use through collective effort.

- Reducing energy cost by investing on local renewable energy projects and in long term free up money, that otherwise spent on fossil fuels, to be spent in the community.
- Improving the living conditions in houses and community buildings, by controlling how houses are heated, lighting systems.
- Bringing the community closer and contribute to goals such as green tourism, eco-congregation, and tidy town activities.

The SEC handbook also maps out a framework for communities in Ireland to become Sustainable Energy Communities under the SEC Network, which is designed to enable SECs engage and learn from each other through site visits, seminars, events, and case studies. The framework described in the SEC handbook is a welcomed simplification of the Guidelines for a Sustainable Energy Community, released in 2010. The guidelines outlined the following steps:



Source: (Heaslip et al., 2016)

Figure 1-1: Summary of SEAI's Guidelines for a Sustainable Energy Community

The current SEC Handbook from SEAI simplifies the process to include the following three stages (SEAI, 2018d):

i. Learn
ii. Plan
iii. Do

The original guidelines limits community engagement, which aims to involve the community to achieve long-term and sustainable outcomes, processes, decision-making, or implementation.

SEAI recommended community involvement only in the final stages of the planning process and in the implementation (Heaslip et al., 2016). This position is revised in the SEC Handbook, where community involvement is recommended from the very beginning. However, community involvement can be seen to vary in the initial stages of the planning process. With communication between the lay-community and experts usually a challenge, communication in the form of public consultations or meetings were realized in the SECs reviewed in both (Heaslip et al., 2016) and (St. Denis and Parker, 2009). Bomberg and McEwen (2012), emphasize the importance of mobilization for SECs in the UK, noting that, “effective mobilization is a precursor to the energy action discussed in many existing studies of community energy” (Bomberg and McEwen, 2012).

1.3. Community Energy in Loop Head

The IC 2020 report has expounded on the community energy planning process in the context of the Loop Head peninsula. In this year’s international class, the LEAP Energy Academy presents an opportunity to consolidate the work of IC 2020. In the aspect of community engagement, the LEAP Energy Academy presents an avenue to inform and familiarize the community with basic topics, concepts, terminologies relevant to community energy. This is discussed in detail in the community engagement chapter. The modelling tool developed in IC 2020, is identified as a major focus for IC 2021, to simplify and improve the IC 2020 model. The improvements made are cognizant of the realities of the Loop Head peninsula, in terms of the community’s objectives, the available renewable energy potential and the applicable SEAI grants. Furthermore, energy efficiency was identified as a major energy related problem in Loop Head and as such received significant attention. Anaerobic digestion was identified by the community members interviewed by IC 2020 as the favoured technology for a community energy scheme. As part of the activities for IC 2021, the use of anaerobic digestors for farming establishments in Loop Head was studied. This study was a part of the research conducted on the concept of circular economy and its potential applications in Loop Head, primarily in the farming sector. With the main deliverables of the IC 2021 being the workshop, model, and report, it is the hope of the students that, the outcome of IC 2021 will kickstart the next phase of the community energy journey of the Loop Head Peninsula.

1.4. Loop Head Community Energy Engagement Study by IC 2020

In the previous year, the International Class of 2020 (IC 2020) acknowledged the importance of community engagement during their trip to the Loop Head community. The pre-feasibility study activities of the IC 2020 understood the challenges, ideas, and future aspirations of the community members on the energy use/sector from the community's viewpoint. This was crucial to creating an alignment with the community objectives and the objectives of the International class. The findings of the study from the previous year helped the IC 2021 study team to better understand the status of energy sector of the peninsula. It also provided a guidance to drive forward the community energy planning in Loop Head.

The IC 2020 conducted two workshops with the community to understand the status-quo of energy consumption, and the community's potential needs going forward. The workshop had identified that the major energy-related problem in the Loop Head community was with energy efficiency and insulation in residential buildings. This was due to many of the old buildings, which have poor insulations and were hard to retrofit. The farms were facing difficulty to manage slurry, especially during the wintertime. The community also faced a problem with public transport facilities and lacks access to national gas grid. Currently, in the Loop Head area, Clare Accessible Transport (CAT) operates only 2 days a week on Wednesdays and Fridays (Clarebus, 2021). The nearest injection point is located in Ennis, 55 km from Kilkee, which requires a very high investment cost (IC, 2020). Also, they were unaware of different grants for different agencies and were concerned about the potential environmental impacts of energy projects. To this, the workshop had identified energy generation from waste or slurry as a potential solution.

The community had been interested in upgrading the heating system in old buildings, developing small scale solar and wind farms, conducting a pre-feasibility study on an Anaerobic Digestor for energy generation and optimizing energy to reduce CO_2 emissions by retrofitting old buildings. However, there were some challenges in the community to implement energy-related projects. One of the major issues identified was the lack of knowledge of best practice in energy efficiency and energy project. The community also lacked expertise in the financial and technical management of the project.

During these workshops, it was also identified that it is necessary to have active participation of the community member to develop a successful energy project. For this to happen, the community members should be able to understand various energy technologies and terminologies so that they understand the activities being carried out. A better understanding of the technology, the background of the technologies and the interaction of individual technologies with the energy system can enable the community members to participate in community energy projects. This will encourage community members to have a discussion on the energy-related topic and provide feedback, which is important to develop a community energy project.

2. Objectives

As direct interaction with the community during this year's study (IC2021) was limited, the objectives for the study were defined based on online interaction with the community and learnings from the IC2020 report.

- Support the community to understand technical aspects and underlying economics of renewable energy and community opportunities via community engagement.
- Identify/explore the possible area, which addresses community's interest for achieving energy sustainability in the peninsula.
- Analyse possible solutions to achieve energy sustainability in the peninsula.
- Develop an interactive energy modelling tool which empowers the community to initiate a qualified dialogue on energy transition.

3. Scope of the Work

The scope of IC 2021 covers the identification of measures for achieving building efficiency in the residential sectors of Loop Head along with designing of PV systems for the residential sector. The study also intends to analyse the possibility of implementing circular economy in the farming sector via integration of energy efficient technologies and self-renewable energy generation like PV system and anaerobic digesters. Besides, the study aims to interact with the community to obtain inputs to design an overall community energy modelling tool. The development of this tool will integrate the details of residential and farming sector along with the commercial sector in the peninsula. Finally, IC 2021 will conduct interactive workshop and training sessions to enhance the capacity of Loop Head community in energy sector.

4. Residential Sector

4.1. Energy Efficiency in Residential Sectors

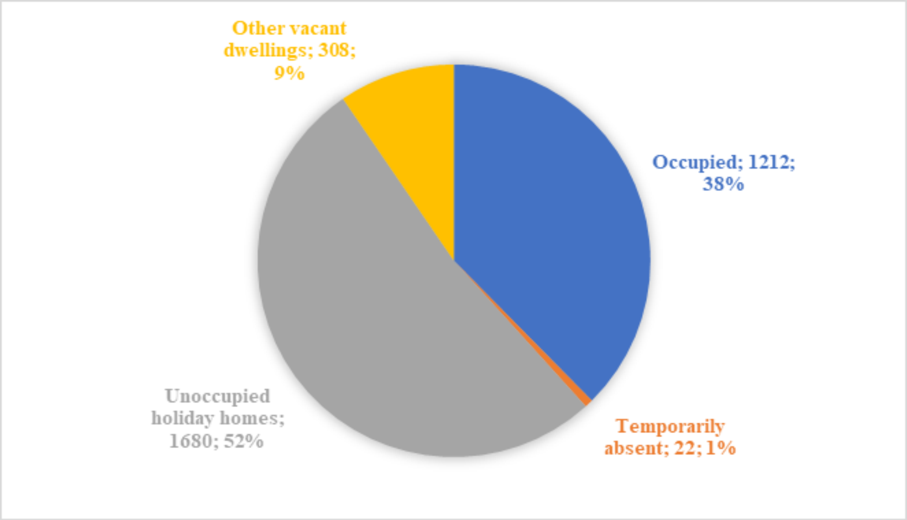
4.1.1. Background

This chapter discusses the potential factors that affect energy consumption in residential sector in Loop Head peninsula of Ireland. One fourth of electricity and heat demand in Ireland belongs to residential sector (SEAI, 2020c). Meanwhile, around 80 percent of energy supply source for residential sector has been produced from fossil fuel which has been responsible for nearly one fourth of CO2 emissions (SEAI, 2018a). However, Ireland supports the European Union targets towards the reduction of CO2 emission from non- industrial sectors by 20% by 2020 and increase energy efficiency of the economy by 20% as well (Government of Ireland, 2020). In this view, the residential sector can contribute to achievement of these targets significantly. As stated in (Gianluca Trotta, 2018) energy efficiency improvement is an one of the cost-effective way to decrease the CO2 emission, that can protect environment, enhance economic growth and unleash investment opportunities. This chapter discusses the potential factors that affect energy consumption in residential sector in Loop Head peninsula of Ireland.

Various institutional arrangements, relevant policies and financial schemes have been initiated to enable energy efficiency across key sectors of economy in Ireland. For instance, to promote Building Energy Rate (BER) improvement in Ireland, SEAI initiated the Better Energy Homes (BEH) scheme which provided grants to support houseowners to improve energy efficiency in terms of building elements insulation and upgrading heating system such as a heat pumps installation (SEAI, 2019). Hence, there are good opportunities for residential sector to not only reduce the dependency on fossil fuels but bring social and economic benefits for communities. Various institutional arrangements, relevant policies and financial schemes have been initiated to enable energy efficiency across key sectors of economy in Ireland. For instance, to promote Building Energy Rate (BER) improvement in Ireland, SEAI initiated the Better Energy Homes (BEH) scheme which provided grants to support houseowners to improve energy efficiency in terms of building elements insulation and upgrading heating system such as a heat pumps installation (SEAI, 2019). Hence, there are good opportunities for residential sector to not only reduce the dependency on fossil fuels but bring social and economic benefits for communities.

4.1.2. Residential Sector Heat Demand

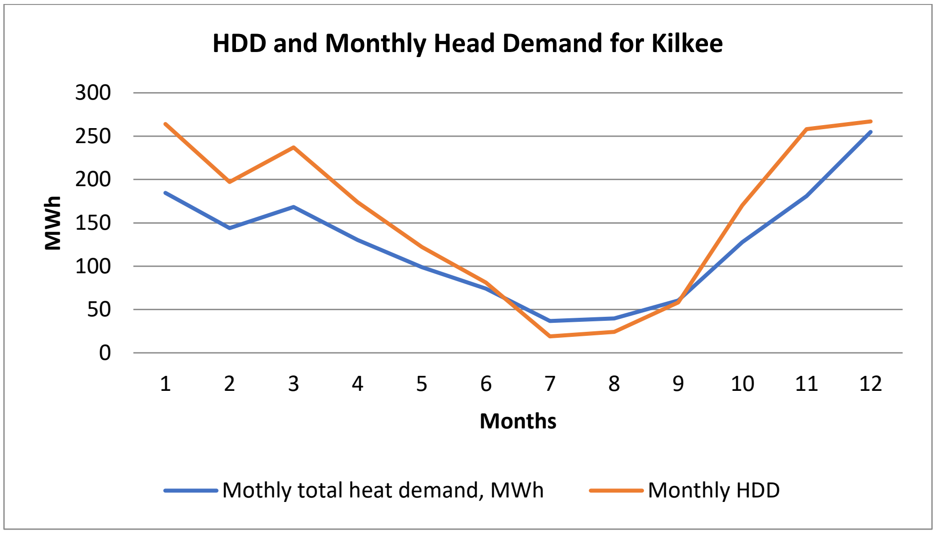
To produce a local statistical database for the composition of building mass, data on population and households was derived and summarized from administrative statistical database (Central Statistic office, 2016). As per Central Statistics Office (CSO) in Ireland, in Loop Head there are 22 small areas under 10 electoral divisions. The estimated total population amounted to 2893 which also includes Einagh, recently added tenth electoral division (Central Statistic office, 2016). As depicted in Figure 4-1, 52% of all houses (1680 houses) in Loop Head accounted for unoccupied holiday houses, while 38% (1212 houses) are occupied houses.



Source: Author elaboration based on (Central Statistic office, 2016), (SEAI, 2018c)

Figure 4-1:Share of Dwellings by Occupancy Status in Loop Head in 2016

According to the interactive maps data from Heat Demand Map (SEAI, 2018c), total heat demand for each small area is used in order to identify monthly values of heating demand for space and water. The conversion from annual values to monthly values is made based on heating per capita parameters and weather data on heating degree days (HDD) in Ireland. Total heating demand and water heating demand in residential sector for whole Ireland are 31.4 TWh and 5.9 TWh respectively (SEAI, 2018a). By dividing by the total population of Ireland, water heating demand per capita was calculated. Then annual water heating demand for each small area was calculated as water heating demand per capita multiplied to the total population of people of each small area. Space heating demand for each small was found by subtracting water heating demand from total heat demand, which was derived from Heat Demand Maps (SEAI, 2018c). Then, space heating demand per capita was divided to total heating degree days, which is 1871 in 2019 (Degree Days, 2021). Attributing space heating demand per capita/HDD for each month respective heating degree days and dividing annual water heating demand to 12, monthly values of heat demand which is the sum of water heating demand and space heating demand for each area were calculated. The Figure 4-2. shows that changes in heat consumption are in line with changes in heating degree days.

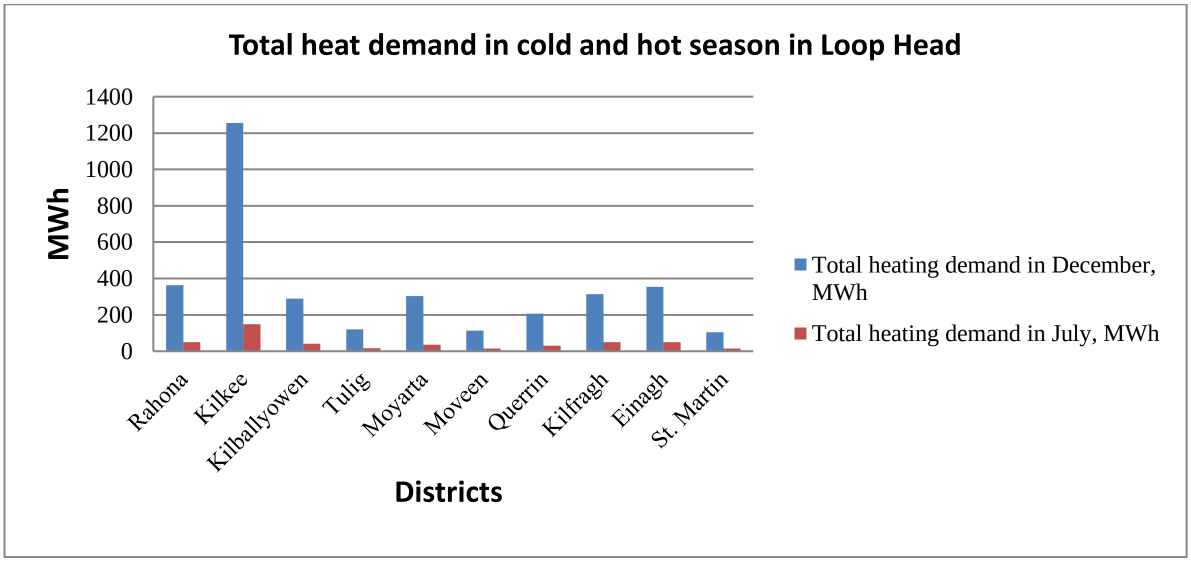


Source: (Author elaboration based on (SEAI, 2018c), *(Central Statistic office, 2016))*

Figure 4-2:HDD and Monthly Heat Demand for Kilkee (code: 037077001/037077002/037077003)

As seen from the Figure 4-3, total heat demand in December across all districts are in the order of 100 MWh to 380 MWh, while in July the heat consumption is nearly in the range between 50

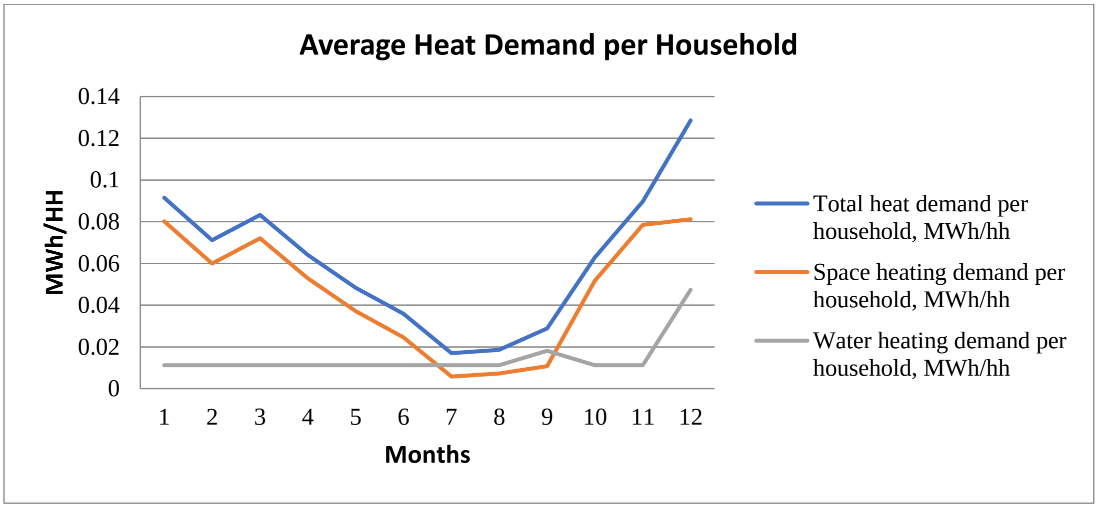
MWh. Kilkee is the district with highest heat consumption in Loop Head with heat demand in December stands at 1254 MWh.



Source: Author elaboration based on (SEAI, 2018c), (Central Statistic office, 2016).

Figure 4-3:Total Heat Demand in Cold and Hot Season by District in 2016, MWh.

Estimated total heat consumption for Loop Head is 18,733 MWh/year, out of which 15,151 MWh/year heat consumption goes to space heating, and 3,582 MWh/year is consumed for water heating. Average heat consumption per household for space and water heating are depicted Figure 4-4, assuming that fuel technology are the same across all districts.



Source: Author elaboration based on (SEAI, 2018c), (Central Statistic office, 2016)

Figure 4-4:The Average Total, Space, Water Heat Demand per Household.

4.1.3. Housing Stock Characteristics

The housing stock characteristics of the residential sector in Loop Head were classified according to their relevance to understanding of energy use and monitoring energy efficiency measures effect. The following eight dwelling age bands were distinguished with corresponding type of dwelling, envelope material and total number of households that belong to each age band. In 2016 the highest share which is 22% share of housing stock represents buildings constructed after 2005, and second largest share of houses, 16% represents old houses built before 1919 (Central Statistic office, 2016).

According to the Table 4-1 the most common type of building which can be found in each age band category is detached house. The most common materials of envelope are cavity walls and timber frame.

Table 4-1. The Classification of the Building Characteristics in Loop Head

Household period of construction	Type of Building	Building Envelope	Total number of

			occupied Households
Pre 1919	Detached House, End of terrace house, Terraced house, Bungalow	stone walls, solid brick walls	188
1930-1949	Detached bungalow, Terraced house	mass concrete	133
1950-1966	Bungalow, Semidetached, Terraced house, Apartment	hollow block, solid brick & concrete walls	89
1967-1977	Detached Bungalow, End of terrace house	cavity walls	96
1978-1982	Detached house, Terraced house	cavity walls, Hollow block	144
1983-1993	Detached bungalow, Semidetached house, Terraced house	cavity walls, Hollow block	117
1994-2004	Detached bungalow, Terraced house, End of terrace house	cavity walls, Timber frame	170
2005-2010	Detached bungalow, Semidetached house, Terraced house	cavity walls, Timber frame	262

Source: (TABULA, 2014) and (Central Statistic office, 2016)

4.1.4. Energy Efficiency Potential in Buildings

Energy efficiency in building can be gained through various options including refurbishment, advanced heating system and renewable technologies and heating/cooling control system. One of the cost-efficient ways to improve the energy performance in existing houses may be to apply retrofitting measures. In this project, a model for evaluating BER rate improvement measures was built. As a part of this model, a potential energy savings cost curve was developed based on the original data of (TABULA, 2014). The aim of this curve is to inform users and help to compare costs associated with certain amount of intended energy savings in building stock.

For the analysis of the effect of retrofitting measures, data on housing stock characteristics in Ireland from European building typology Tabula database was used. Eight representative buildings, all of which are detached houses, were selected for each period of construction, assuming that they have the same gross floor area. The retrofitting measures at advanced level with associated costs of investments were compiled for each house. Primary energy demand before and after refurbishment that were further converted to useful energy, was used to quantify the energy savings related to each saving option. It was assumed that all building under each age category have the same energy demand, the same heating technology and belong to the same building type. Based on total energy savings per area of building surface and total investment cost of refurbishment activity, the cumulative cost of the last retrofitting measure and corresponding energy savings in MWh per year for one house were calculated.

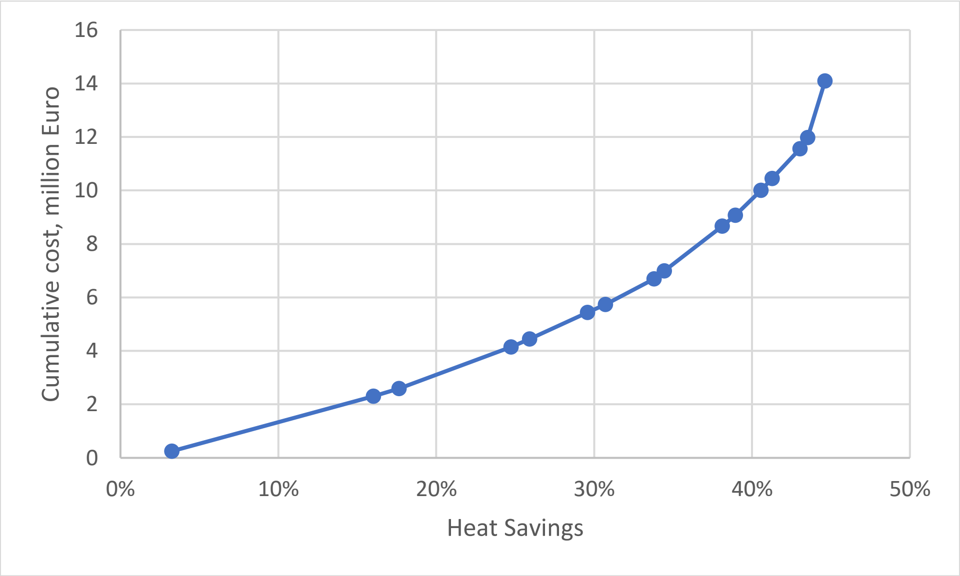


Figure 4-5: Cumulative Energy Cost Curve

Looking at the Figure 4-5, it could be inferred that to reach the heat savings at 30% of energy demand in housing stock in Loop Head, total investment costs at 6 million Euro would be needed. Potential savings of 35 and up to 42% of energy demand are observed with relatively high costs of retrofitting measures. This could be explained by lower energy demand before introducing retrofitting.

4.1.5. Case Study of Energy Refurbishment for a Selected Building Type

This study aims to describe one representative house with relevant physical characteristics to analyse the effect of energy efficient measures on heat consumption. It is important to note, that due to lack of data and access to real existing houses, in-depth analysis of thermal and energy performance was deemed infeasible. However, based on data (TABULA, 2014), house characteristics and cost of retrofitting measures was used for this study. The selected house was built before 1919 with no prior deep renovation made and connected to central oil-heating system with 70% efficiency.

4.1.5.1 Pre-refurbishment parameters

Table 4-2. Pre-refurbishment Parameters of the Selected House

	Material	**Current U-value, W/m^2**	**Surface Area, m^2**	**Current heat losses, kWh/m^2**
Wall	Solid stone	2.1	80	168
Roof	Pitched, insulation between joists	0.68	100	68
Windows	Single glazed, wooden frame	4.8	40	192
Door	Solid timber	3.0	20	60

The U value, which expresses how well insulated the material of envelope are, was taken as an input to calculate heat losses as well as floor are of each building components. The values of floor areas for each element are rough assumed values based on Tabula database records (TABULA, 2014).

To assess the energy efficiency measures and understand the potential savings of cost and fuels, two scenarios were developed. The first scenario sets to analyses application of retrofitting measures and their effect on heat losses. The second scenario was built as a further improvement step for the selected house with introducing new heat technology to replace the oil boiler.

4.1.5.2 Energy efficiency scenario 1- Retrofitting measures

Due to a limited data on different types of retrofitting measures of different building components, for the scenario analysis, standard packages of retrofitting activities was selected from (TABULA, 2014). The heat demand before retrofitting measures amounted to 42.2 MWh/ m^2/y. It was assumed that the roof would be insulated by an additional layer of 200 mm mineral wool, while walls would be insulated by applying approximately 120 mm of external insulation which brings the U-value of roof and wall to 0.13 and 0.27, respectively. Door and windows would be replaced to more efficient ones with double-glazed frame and sufficiently insulated doors. Based on these considerations, heat losses after implementing all refurbishment activities were amounted to 26.2 MWh. Consequently, energy demand was reduced to 160 kWh/m^2/y that lies under the range of energy consumption of BER rate C1. Investments costs of retrofitting measures, corresponding energy savings and reduced heat losses are compiled in Table 4-3.

Table 4-3. Investments Cost and Related Energy/Cost Savings for 1 Scenario

	Investment costs, Euro	**Reduced heat losses, kWh**	**Energy savings, kWh/m^2/y**	**Energy savings, %**	**Investment cost of savings, Euro/kWh/y**
Roof insulation	1,322	3,528	35.3	8	0.37
Wall + roof insulation	30,886	13,535	135.3	40	2.85
Wall + roof insulation +	36,941	26,236	262.4	52	3.26

Window and Door					

4.1.5.3 Energy efficiency scenario 2 - Retrofitting measures and replacing oil-boiler with more efficient heating technology.

Online workshops, open discussions and results of interview through online survey questionnaire during the Training program showed a high interest of community members about new heating technology that can reduce oil consumption for existing heating system and reduce energy bills (see Appendix A). The growing interest also can be supported by SEAI grants to refund a certain amount of investment cost. One of the requirements of eligibility for a grant is low heat losses (SEAI, 2020b). This can be achieved through well insulated building envelope and renovated windows and doors. Hence, this scenario is based on the result of 1st scenario when all retrofitting measures are implemented.

As alternative options for old oil heating system three types of heat technologies were analysed. Relevant calculations of investment cost, operation and maintenance costs, fuel costs, fuel saving are compiled in excel file. The technical characteristic on efficiency, nominal capacities and coefficient of performance were derived from (Danish Energy Agency, 2016).

The investment cost, operation and maintenance costs were obtained through (European Comission, 2017). Fuel prices for oil, electricity and wood pellets have been derived from (SEAI, 2021a). CO_2 emission intensity factors for each type of fuel have used from (SEAI, 2016b). The Table 4-4 below contains the results of calculations of costs, CO_2 emissions and fuel savings.

Table 4-4. Financial and Energy Calculations for Heating Technologies for Selected House

	Oil boiler (current system)	**Heat pump air-to air**	**Heat pump air-to water**	**Biomass boiler**
CAPEX, Euro		11,790	26,270	5230
OPEX, Euro/kW/year	28.26	117.9	52.54	335

Fuels costs, Euro/year	4117	876	1051	1442
Secondary energy demand after retrofitting, kWh/year	16,054	16,054	16,054	16,054
CO2 emissions, tCO_2/kWh	4.2	1.8	2.1	0.2
Grants		600	3,500	
Cost savings, Euro/y		3,241	3,065	2,675
Total investment (1+2 scenario)		43,075	57,555	36,515

All three heating technologies, particularly heat pumps air-to air, heat pump air-to water and biomass boiler have lower CO_2 emission value and higher energy savings in comparison with oil boiler system. The cheapest option seems to be biomass boiler with 5,230 Euro of investment cost. Also, grant for installation of heat pump air-to water and heat pump air-to air are available from SEAI (SEAI, 2020b).

4.1.5.4 Case study results

This case study can help in bringing understanding of energy efficiency measures in buildings, their relevance to energy consumption and household expenditures on fuels. It can add strength to the existing knowledge about insulation of building envelope, BER rates and range of available heating technologies with efficient operation characteristics. First scenario showed that the total investment cost for the whole package of retrofitting measures is 36,941 Euro. The initial heat demand was amounted to 42.2 MWh/y. After insulating roof, and replacing windows and doors, total heat demand was decreased to 16 MWh/y. The second scenario entails combination of retrofitting measures and replacing of existing oil heating system with heat pumps. Considering the lower investment cost in comparison with heat pump air-to air, it is worth to consider wood pellets boiler with investment cost 5,230 Euro and cost savings on fuel amounted to 2,675 Euro in a year. The next cheaper option is heat pump air-to air with investment cost 11,790 Euro and reduced expenditure on oil at 3241 Euro in a year. Considering the 1st scenario, total investment cost would be 43,075 Euro for implementing retrofitting measures and installation of heat pump air-to air. Considering that this technology uses clean way of producing energy, the scenario with this heating system has huge potential to reduce household expenditures and contribute to sustainable development of community.

4.1.6 Conclusion

Based on the analysis of energy demand, marginal energy cost curve and results of simulation of scenarios for one selected house several conclusions were drawn. The energy demand, particularly heat demand in residential sector, are determined by weather conditions, winter/summer season temperature patterns, housing stock parameters such as age of building, number of buildings. The heat savings in buildings and associated costs are closely linked with building envelope material and level of insulation. Moreover, replacing oil boilers with more efficient clean heating technologies can reduce household's expenditures on fuel and their carbon footprint.

4.2. PV System Design for Residential Buildings

4.2.1. Residential Demand

To calculate the hourly residential demand, the average demand of a household in Ireland was extracted from (Ricardo, 2020). From this source, a weekday and a weekend day demand profile per season were taken. The total energy consumption obtained does not match the average electricity consumption in Loop Head calculated in (Students EUF, 2020), for this reason, the values were scaled, to sum up, a total of 4245kWh/household/year. This value is the result of dividing the total energy consumption in the residential sector (EUF Students, 2020) by the total number of occupied households (EUF Students, 2020). The final values for the residential demand can be observed in Table 4-5. To calculate the hourly residential demand, the average demand of a household in Ireland was extracted from (Ricardo, 2020).

Table 4-5: Values for Residential Demand Profile

Hour	Autumn weekday hourly demand (kW)	Autumn weekend hourly demand (kW)	Winter weekday hourly demand (kW)	Winter weekend hourly demand (kW)	Spring weekday hourly demand (kW)	Spring weekend hourly demand (kW)	Summer weekday hourly demand (kW)	Summer weekend hourly demand (kW)
0	0.385	0.435	0.460	0.522	0.404	0.438	0.379	0.416
1	0.280	0.329	0.329	0.385	0.292	0.345	0.273	0.317
2	0.242	0.267	0.280	0.311	0.255	0.283	0.242	0.261
3	0.230	0.242	0.261	0.273	0.236	0.249	0.230	0.239
4	0.230	0.236	0.249	0.261	0.236	0.236	0.224	0.236
5	0.236	0.236	0.267	0.264	0.236	0.245	0.230	0.236
6	0.292	0.261	0.342	0.298	0.298	0.261	0.280	0.252
7	0.479	0.342	0.565	0.401	0.479	0.354	0.447	0.339
8	0.615	0.479	0.777	0.556	0.603	0.491	0.541	0.447
9	0.541	0.584	0.677	0.696	0.541	0.590	0.503	0.547
10	0.510	0.640	0.615	0.758	0.516	0.643	0.479	0.600
11	0.479	0.634	0.590	0.795	0.479	0.668	0.460	0.612
12	0.497	0.677	0.597	0.826	0.497	0.730	0.472	0.656
13	0.491	0.684	0.597	0.833	0.497	0.690	0.460	0.640
14	0.454	0.584	0.553	0.736	0.454	0.584	0.429	0.559
15	0.454	0.547	0.578	0.724	0.460	0.559	0.435	0.531
16	0.528	0.578	0.727	0.795	0.541	0.590	0.516	0.544
17	0.721	0.671	1.038	0.997	0.708	0.674	0.671	0.609
18	0.783	0.746	1.143	1.119	0.727	0.736	0.677	0.637
19	0.851	0.858	1.112	1.109	0.708	0.715	0.634	0.628
20	0.851	0.851	1.019	1.028	0.733	0.746	0.590	0.593
21	0.826	0.802	0.963	0.938	0.814	0.805	0.621	0.597
22	0.746	0.721	0.864	0.845	0.777	0.743	0.671	0.646
23	0.578	0.597	0.671	0.687	0.609	0.615	0.559	0.569
Total	**12.297**	**12.999**	**15.273**	**16.159**	**12.098**	**12.990**	**11.023**	**11.709**

(Source: Author)

As expected, winter is the season with the highest electricity consumption, while summer is the one with the lowest demand. Regarding the daily profile demand, in general, in all the seasons there are two daily peaks at 9 am and 7 pm approximately, where the second one is the highest. This information will be highly relevant for households with rooftop solar systems, where there are different energy tariffs for energy sold and energy consumed to/from the main electric network.

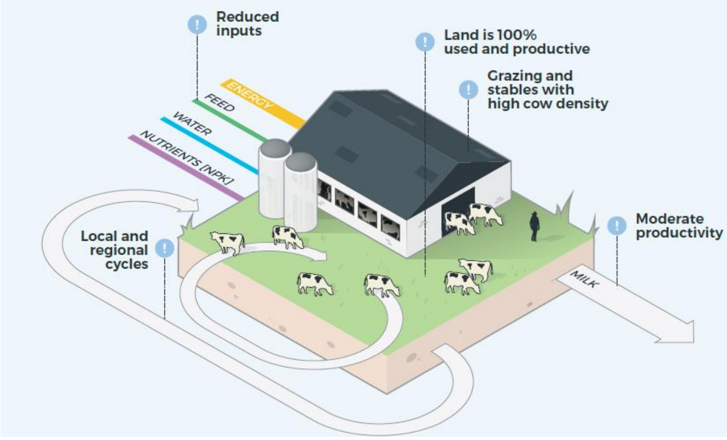
4.2.2. Roof Top Solar for Residential Sector

An interactive excel based model was developed by the team which can estimate the solar roof top potential of the farm and optimize the size of the system as per need. The tool permits the sizing of PV roof top system both for standalone residents and farms with residents. The details on the tool is provided under the farming sector in Chapter 5.2.2.

5 Farming Sector

5.1 Circular Economy in Farms

Agriculture is a major economic activity in Loop Head. As per the interview's conducted by IC 2020 and virtual interactions with the local farmers during this study, dairy and beef farms were identified as centre of the farming sector in the peninsula. However, both sectors, more specifically the dairy farms are highly energy intensive with most of their energy demands met from the burning of fossil fuels. Though the farms are working towards reducing their carbon footprint and implementing sustainable operational practice, the linear make and waste system in these sectors may no longer be feasible considering the limitations in the natural resources availability. Even though no specific concerns were expressed by the farmers regarding their linear operation model, a transition towards a more circular approach for these farms in Loop Head could provide opportunity for long term economic, social, and environmental benefit. Therefore, IC 2020 has explored possible interventions to ensure a shift of the sector towards a vision of more circular operational model.



Source: (Circle Economy, 2016)

Figure 5-1: Circular Dairy Vision

The Figure 5-1 extracted from (Circle Economy, 2016), provides a visual representation of a circular operating model in a dairy farm which is envisioned by this study. The Circle Economy report focused on implementing dairy circularity defines it as “the approach to decouple economic growth from the consumption of natural resources, to achieve regenerative net positive impact” (Circle Economy, 2016). This study is thus a catalyst towards accomplishing this vision for dairy farms in Loop Head. All the environmental aspects of circularity detailed by the Dairy Sustainability framework (Circle Economy, 2016)are covered by the following targets for Loop Head farms.

- Zero or negative GHG emissions
- Closed soil nutrient cycles.
- Zero waste generation
- Water recovery and reuse
- Soil and Land preservation
- Biodiversity in the business model

As an approach to achieve circularity in Loop Head farms, this study will focus on three aspects: making the farms in Loop Head more energy efficient, energy self-sufficient and have sustainable waste management. These working areas were identified based on the study conducted the previous year (IC 2020) and by understanding the needs and priorities of the local farmers through virtual interactions over the period of the study. Though these three areas do not fully cover the aspects of a circular economy, these are a starting point for the farms towards the transition.

The open field disposal of cattle manure in farmlands for grass cultivation for grazing is a common practice in Loop Head. This provides a degree of soil nutrition recirculation but also result in emission of large amount of methane into the atmosphere. About 0.29 tons per annum of CO2 equivalent is estimated from a cattle (Blades et al., 2017). Considering the farm size in Loop Head vary from 25 to over 300 cattle, substantial emissions are expected from each farm. Also, the soil nutrient leaks, wastewater, and large volumes of unused agro by-product account for a waste of valuable resources in the farms. The implementation of circularity thus allows the mitigation of these emissions and adds value to the unused waste providing additional revenue source for the farm. In addition to the micro economic benefits the transition of the farm towards a circular business model contributes towards the Irish vision of long-term low carbon energy systems (SEAI, 2020a).

As mentioned above, this study has identified the three-working areas for initiating circularity in dairy farms. Energy efficiency is an important point of departure for circularity with an aim of decreasing the difference between the energy used and total energy consumed. The thermal energy requirement of farms is identified as potential immediate points of intervention for improvement along with the introduction of newer technologies are a possibility.

With regards to self-sufficiency in energy/electricity generation, the possibility of installation of PV system has been identified as potential technology considering high local interest. Also, numerous success stories in individual solar systems in Loop Head and expected implementation of new feed-in tariffs in the coming years has made the technology a point of high interest. Further, survey results conducted at the beginning of the study verified high interest in the technology with many respondents showing willingness to invest in solar technology amongst the farmers.

The final issues regarding the management of waste in farms is planned to be addressed with the studying the feasibility of anaerobic digestion technology for individual farms. National Irish studies show the storage of 81-83% of the manure in the form of slurry (Buckley, 2020). As a result, the emission of methane is quite high from the sector. Capturing the methane, while extracting energy from this waste source and also using the nutrient in the waste to restore nutrient cycle in the farm is an approach undertaken by the study.

For both PV systems and anaerobic digestion systems, an interactive stand-alone tool was developed during the study, which allows the farmer to size and estimate the energy potential and financial feasibility of the technology in their respective farms. The working of the tool and findings over the study period are discussed in detail in the following sections. Also, recommendations on an individual scale towards promotion of circularity in the dairy farms of Loop Head have been presented.

Thus, over the study period the team worked on understanding the feasibility and recommending possible avenues for the farming sector in Loop Head to transition towards circularity and as a result towards sustainability.

5.2 Implementing Circular Economy in Loop Head Farms

The study was initiated with a general literature review to better understand the present farming sector in Loop Head and for better understanding of the technology planned to be studied and implemented in Loop Head for circularity. Though secondary literatures were referred to for data gathering, the level of interaction with the community were kept at the maximum throughout the study to get a better understanding on ground situation and get a better perspective on their motivation towards circularity. Also, during the study period, a workshop was carried out with the community to present the team's view and objectives of the study.

5.2.1 Energy Auditing

Benchmarking is particularly relevant as starting point of an energy audit since it allows estimating the potential savings that might be expected after conducting a complete energy audit. Therefore, the International Class team has conducted research on the different types of farms in Loop Head to find the average electricity consumption per livestock for each type of farm. By doing that we aim to provide to the farm owners the parameters that allow them to compare their electricity consumption with the average values of the community.

A more detailed analysis is required for each individual farm to analyse where the electricity is consumed and provide tailored energy conservation measures for each farm. A detailed questionnaire (Appendix C) was developed to evaluate the appliances that consume more electricity in dairy farms and give recommendations to the farmers; however, due to time limitations this survey could not be conducted. This questionnaire can be useful for the self-assessment of the farmers as well as future studies. Nevertheless, general recommendations from literature to the dairy sector are relevant to mention to provide insight to the Loop Head farmers and encourage them to analyse in detail how the electricity is consumed in their farm. (John Upton et al., 2010) mentions key opportunities for reducing energy consumption which include:

- Eliminate energy wastage; fix all hot water leaks, insulate all hot water piping and refrigerant gas piping and use lights only when necessary. A leak as small as one litre per hour can waste 8,500 litres of hot water and 3,800 kWh per year.
- Optimize plate cooling by increasing water flow to achieve the correct water to milk flow ratios. Increasing the milk to water flow ratios from 1:1 to 1:3 can reduce power consumed by the bulk tank by over 40%.
- Consider using a variable speed drive controller on vacuum pumps. This can save over 60% on vacuum pump running costs.
- Use energy efficient lighting.

Electricity and Diesel Consumption on Farms

With the objective of find information on the electricity and diesel consumption in the farms in Loop Head Peninsula, we have surveyed through an online questionnaire asking information about the type of farm, number of livestock, electricity, and diesel consumption.

Some of the farmers are living on the farm and the electricity consumption provided in the interview includes both farm and house consumption. To analyse those cases in detail, we asked in the interviews if the electricity consumption includes house consumption or whether it is exclusively for the farm. In those cases where the values include the house consumption, we have deducted 350 kWh/month that is considered in this report as the average electricity consumption for a household in Loop Head.

The online questionnaire submitted to the farmers of the community has been responded by seven farm owners. Additionally, to have as much information as possible, the results of the interviews with the farmers in the IC 2020 were also taken into consideration. A total number of thirteen farms were analysed, four of them are beef producers and nine are dairy farms.

Beef production farms consume significantly less electricity than dairy farms per livestock unit, that is because beef production farms have no high energy-intensive appliances and most of the electricity consumption is due to lighting and some other minor consumptions such as electric fences. Based on the interviews, the average electricity consumption for the beef production sector is 5.61 kWh/cattle/month.

Dairy farms have a higher electricity consumption per cow due to electrical appliances required for milk production. In contrast to the beef production farms, according to (John Upton et al., 2010) lighting in dairy farms consumes only 10% of the electricity while milk cooling is the largest consumer of electricity (37%), followed by water heating (31%) and vacuum pumps (19%). Other items such as wash pumps, milk pumps, feed augers, and air compressors make up the balance (3%). Based on the information collected from the interviews, the average electricity consumption for the dairy sector is 17.44 kWh/cow/month. However, as we identified in the results a significant difference between the values for large dairy farms (more than 100 cows) and small dairy farms (100 cows or less), we have clustered the farms in those two groups and calculated the consequent average. Taking into consideration the farm size, the electricity consumption for large dairy farms is 14.09 kWh/cow/month and for small dairy farms, it is 29.19 kWh/cow/month. Those values are in accordance with literature parameters, according to (John Upton et al., 2010) electricity consumption per dairy cow milked, the figures vary from 4 kWh/cow/week to 7.3 kWh/cow/week. To obtain the monthly consumption, those values are multiplied by 52 and divided by 12, consequently, we obtain a range between 17.33 kWh/cow/month to 31.63 kWh/cow/month.

The results of the interviews performed during International Class 2020 and 2021 are summarized in the table below.

Table 5-1: Results of interviews on electricity demand

Identification	**Farm Type**	**Livestock**	**Electricity consumption kWh/month**	**kWh/ Livestock/Month**
Farm 1	Beef farm	80	580	7.25
Farm 2	Beef farm	60	100	1.67
Farm 3	Beef farm	25	70	2.80
Farm 4	Beef farm	320	3429	0.72

Farm 5	Small dairy farm	85	3422	40.26
Farm 6	Small dairy farm	80	1450	18.13
Farm 7	Large dairy farm	180	4115	22.86
Farm 8	Large dairy farm	110	1650	15.00
Farm 9	Large dairy farm	162	2058	12.70
Farm 10	Large dairy farm	102	1500	14.71
Farm 11	Large dairy farm	120	1189	9.91
Farm 12	Large dairy farm	180	2632	14.62
Farm 13	Large dairy farm	102	900	8.82

Regarding the diesel consumption, as there were no significant differences because of the farm size, therefore, it was not taken into consideration for the calculation of the averages. For the beef production sector, the average monthly diesel consumption per cattle is 3.77 litre/cattle/month. According to the interviews dairy sector has a lower diesel consumption with 3.27 litre/cow/month. The results of the interviews are listed in the table below.

Table 5-2: Results of interviews on diesel demand

Identification	Farm Type	Livestock	Diesel consumption litre/month	Litre/Livestock/Month
Farm 1	Beef farm	80	200	2.50
Farm 2	Beef farm	60	125	2.08
Farm 3	Beef farm	25	100	4.00
Farm 4	Beef farm	320	2083	6.51
Farm 5	Small dairy farm	85	417	4.90
Farm 6	Small dairy farm	80	150	1.88
Farm 7	Large dairy farm	180	83	0.46
Farm 8	Large dairy farm	110	400	3.64
Farm 9	Large dairy farm	162	167	1.03
Farm 10	Large dairy farm	102	533	5.23
Farm 11	Large dairy farm	120	550	4.58
Farm 12	Large dairy farm	180	500	2.78
Farm 13	Large dairy farm	102	500	4.90

5.2.2 PV System design for Farms

As an approach to promote the community use of PV systems, this study aims to assist Loop Head farmers to identify suitable PV system size for their farms and understand its financial viability. The analysis was, therefore, developed considering the possible factors that people could find useful to make these decisions. The activities were divided into three different stages:

i. ***Stage I: Definition of expected outputs**:*

During this stage, all the possible information that could help in the decision-making process was proposed, analysed, and selected. In the end, some economic, technical, and environmental factors were selected.

ii. ***Stage II: Collection of required inputs***

Once the required outputs were defined, the process of data collection started. Each one of the outputs requires different inputs to be calculated and all of them were listed and searched. During this stage, specific data from the Peninsula was the priority. For this, the previous report on the field (Students EUF, 2020) was consulted and surveys were designed, applied, and analysed. When it was not possible to find specific data from Loop Head, national data were used like in the case of prices for different configurations of solar rooftop systems (Government of Ireland, 2019).

iii. ***Stage III: Calculation development***

With all the required information collected, in the last stage all the outputs defined in the first stage were calculated. Microsoft Excel was the selected software to develop the Solar Calculator, due to its high flexibility and wide range of uses. This tool was designed to be used at the individual level to provide financial and technical information about a possible investment in the mentioned technology.

Dairy farms demand

The farms dedicated to milk production have an electricity generation that depends directly on the number of cows. From the interviews, the next functions were calculated:

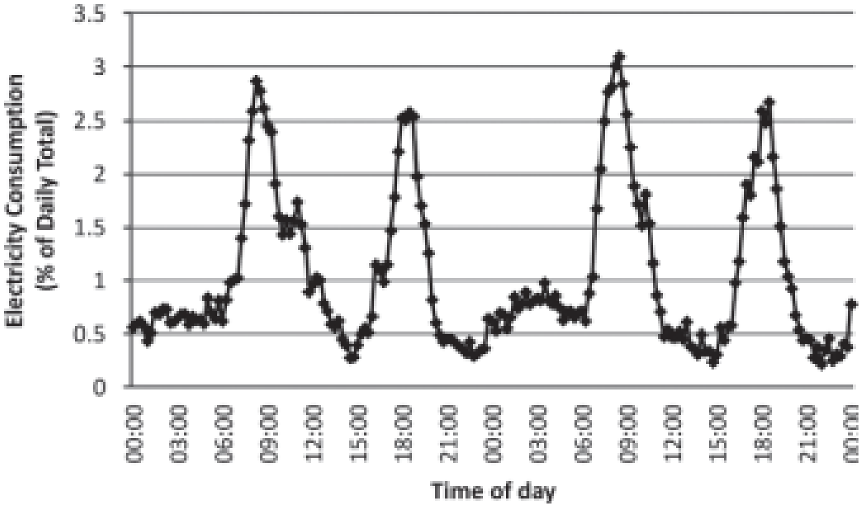
When the number of cows (C) is more than 100:

Weekly electricity consumption = C * 14.09 kWh/cow

When the number of cows (C) is less or equal to 100:

Weekly electricity consumption = C * 29.19 kWh/cow

Once the amount of energy is calculated, how that energy is consumed during the day can be presented in hourly resolution. For this purpose, the shape is shown in Figure 5-2 (J. Upton et.al, 2013) is used. This shape shows the measurements of energy consumption for 22 dairy farms for two consecutive days in Ireland (J. Upton et.al, 2013) .



Source: (J. Upton et.al, 2013)

Figure 5-2: Example of electricity consumption in Irish Farms

According to (J. Upton et.al, 2013), the highest demand in a dairy farm is milk cooling (30-40% of the total consumption). The results make sense since it is known that milk is extracted twice per day: at 8 am and 4 pm and the two peaks of this load are present in the used shape.

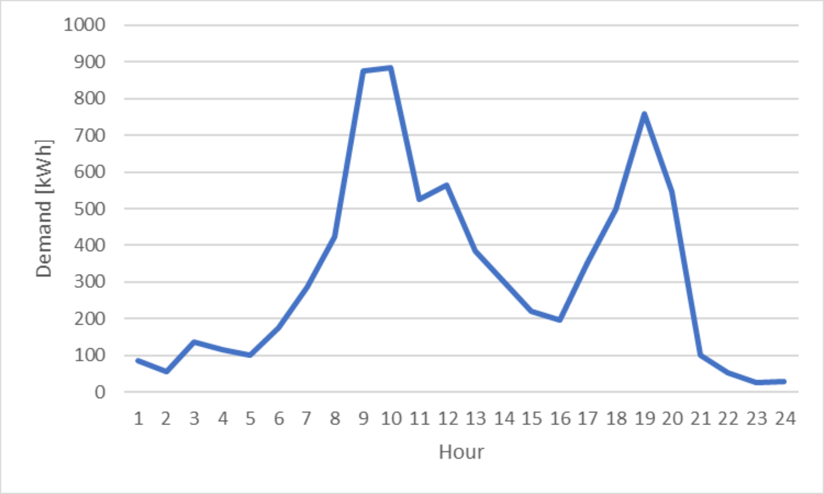
Cattle farms demand

To calculate the hourly load profile of cattle farms, a similar procedure to the one applied to dairy farms was performed. From the surveys, it was defined that on average each cow/bull represents an energy consumption of 5.61 kWh/week. No differences were found between big and small farms.

Regarding the hourly profile, it was assumed that the load is constant in the period between 6 am and 6 pm every day, when someone is present on the farm developing daily activities related to the business. In conclusion, the calculated energy consumption is divided every day into 12 hours.

Total electricity consumption farming sector

Current estimations according to (Central Statistics Office, 2020) affirm that the livestock for dairy and cattle is 11,271 and 7,675, respectively. The 7,675 cows for dairy purposes were divided into two groups: 3,698 in large farms and 3,959 in small farms. Knowing the total amounts, the hourly load demand was calculated using the characteristics demands per sector developed in the previous sections of this report. The result can be observed in Figure 5-3. This demand profile is used for community-level calculations.



(Source: Author)

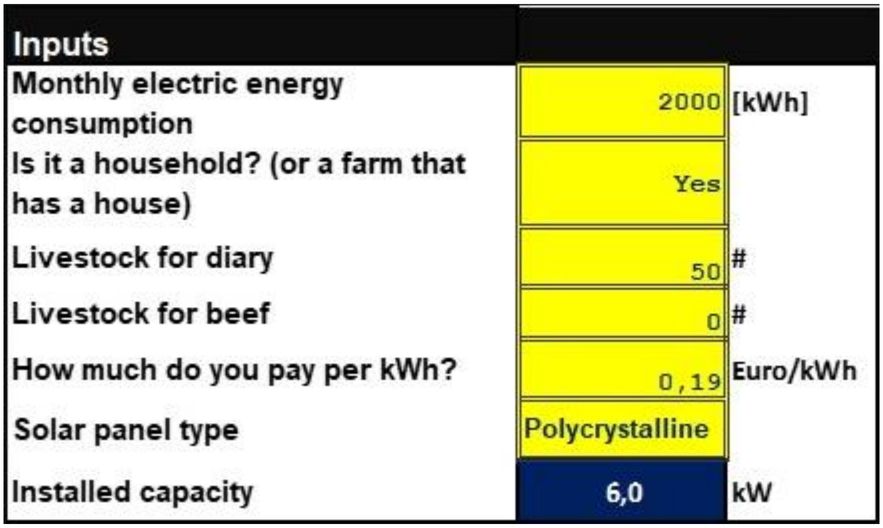
Figure 5-3: Total Hourly Demand Farming Sector.

Analysing Farm Level Solar PV systems

Solar PV systems are called to be the largest source of microgeneration in Ireland (Ricardo, 2020). The current investment costs allow this technology to be financially interesting for household owners due to the potential savings that it can generate. Additionally, the Ireland government supports this technology as part of the Climate Action Plan 2019 and currently offers grants for new investors. In July 2021 is expected to be available the feed-in tariff (Government of Ireland, 2019), which will allow the owners of microgeneration to sell all their surplus of energy to the gird. Currently, that energy was just taken by the main grid without receiving any payment.

The new policies will encourage more people to install rooftop systems, and those people are going to require information that is more specific. For instance, investment and annual savings are very important to make a final decision regarding this kind of investment.

In order to support a well-informed decision-making process, a technical and financial model was developed for the Loop Head community at the individual level. This model will be called in this report Solar Calculator. Households and farmers owners can use this model regardless of their background or expertise on energy topics, since the required inputs are parameters that every person knows or can find easily. The interface and questions can be observed in **Error! Reference source not found.**.



Inputs		
Monthly electric energy consumption	2000	[kWh]
Is it a household? (or a farm that has a house)	Yes	
Livestock for diary	50	#
Livestock for beef	0	#
How much do you pay per kWh?	0,19	Euro/kWh
Solar panel type	Polycrystalline	
Installed capacity	6,0	kW

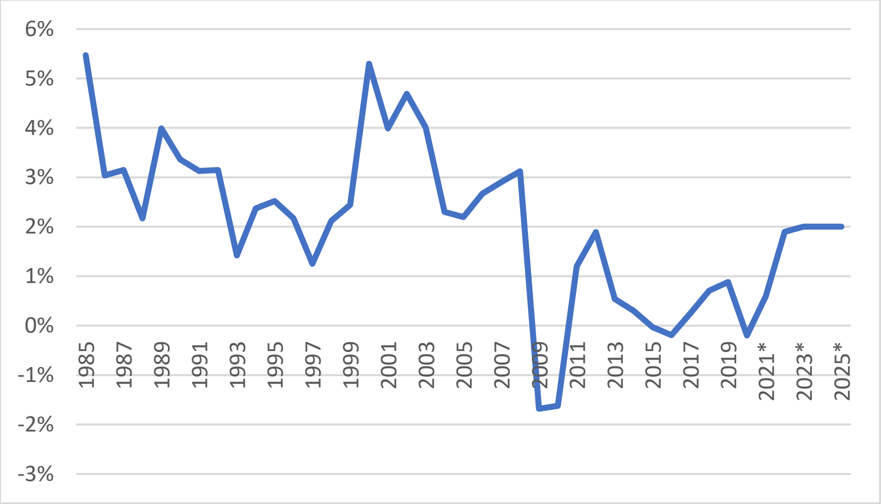
(Source: Author)

Figure 5-4: Inputs rooftop solar systems tool.

The inputs can be divided into three categories: in the first one is the values used to calculate the electricity demand based on the demand profiles calculated at the beginning of this chapter. For this purpose, the monthly energy consumption is used, if it is a household or a farm with a household, beef livestock, and dairy livestock. In the second category are the inputs used to calculate financial parameters: price per kWh and monthly energy consumption. Finally, in the third category are the inputs that are intended for the user to change and find the most optimal system size, based on the comparison of the Solar Calculator and their resources and expectations.

The tool can provide very specific and understandable financial and technical results based on the next main assumptions:

Inflation: The inflation in Ireland has been in a range of 5% to -1.8% in the period between 1985 and 2020 (Statista, 2021a). This parameter has a big impact on financial calculations performed in the present report and should be carefully selected. In Figure 5-5 can be seen the historical values of inflation of the mentioned period. Additionally, the projections for the next 3 years (2021, 2022, and 2023) are available in the same figure. Based on this information, all the calculations performed will use constant inflation of 2% per year.

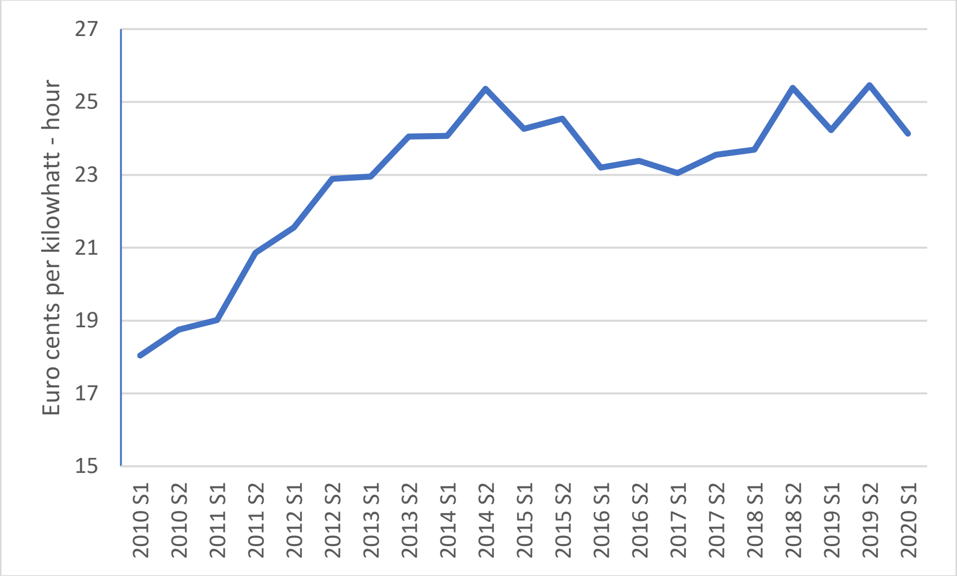


Source: (Statista, 2021a)

Figure 5-5: Inflation in Ireland.

Electricity rates: In the last 10 years, the price of electricity for a household in Ireland has increased 33% approximately (Statista, 2021b). High values of electricity are an important motivation to invest in renewable energies and consider energy efficiency measures. Furthermore, expectations about the future prices of electricity are highly relevant when calculating financial models during the investment decision-making processes.

In Figure 5-6 can be observed the changes in electricity rates in Ireland in the period between 2010 and 2020. It is possible to identify that there was almost a constant increment in the prices between 2010 and 2014, but between 2014 and 2020 the price has been around 0.24 EUR/kWh. Based on this, the electricity rate is going to be considered to increase only due to the inflation in the next years.



Source: (Statista, 2021b)

Figure 5-6: Electricity rated in households

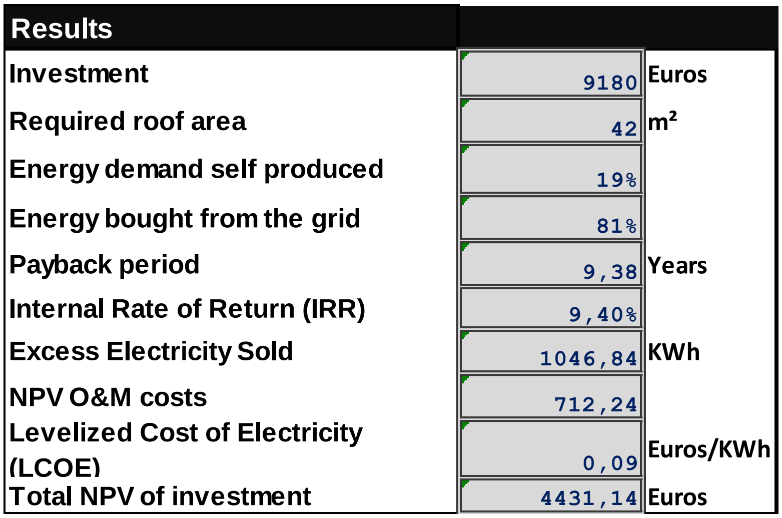
Feed-in tariff: At present, the feed-in tariff has not been implemented in Ireland, but according to (Government of Ireland, 2019), it is expected to be implemented in July 2021. In order to perform financial calculations, the average expected values for this tariff presented in the Economic and policy advice to support the design and implementation of the new microgeneration support scheme in Ireland (Ricardo, 2020) report was used. The values from 2031 to 2041 are the result of considering the same tariff from 2030 plus its inflation. The values can be observed in Table 5-3.

Table 5-3: Feed-In Tariff Used in the Model

Year	Feed in tarif model [EURc/kWh]	Year	Feed in tarif model [EURc/kWh]
2022	5,94	**2032**	7,61
2023	6,69	**2033**	7,76
2024	6,79	**2034**	7,92
2025	7,65	**2035**	8,08
2026	7,20	**2036**	8,24
2027	6,80	**2037**	8,40
2028	6,87	**2038**	8,57
2029	7,31	**2039**	8,74
2030	7,31	**2040**	8,92
2031	7,46	**2041**	9,09

(Source: Author)

Since the motivations for installing a rooftop solar system can be different, the outputs of the Solar Calculator were selected to satisfy the most common questions like total cost, required roof area, payback period, percentage of energy self-supplied among others. The outputs and the interface can be observed in Figure 5-7.



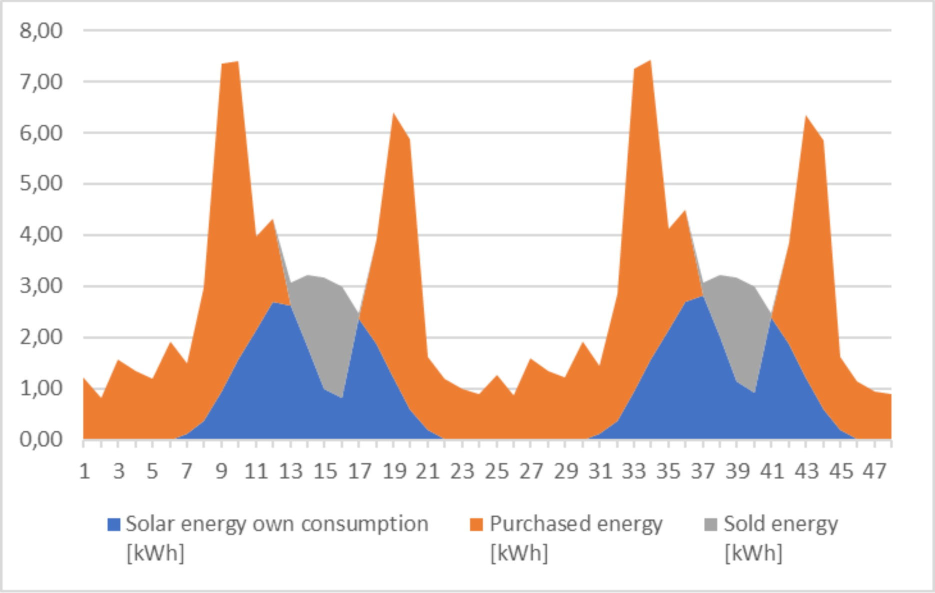
Results		
Investment	9180	Euros
Required roof area	42	m²
Energy demand self produced	19%	
Energy bought from the grid	81%	
Payback period	9,38	Years
Internal Rate of Return (IRR)	9,40%	
Excess Electricity Sold	1046,84	KWh
NPV O&M costs	712,24	
Levelized Cost of Electricity (LCOE)	0,09	Euros/KWh
Total NPV of investment	4431,14	Euros

(Source: Author)

Figure 5-7: Outputs rooftop solar systems too

For most of the users, the values presented previously could be sufficient, but in favour of clarity extra graphical information is produced. The energy balance for a typical day in January and July is shown (Figure 5-8), giving an idea of the seasonal changes. This energy balance shows when the energy produces by the rooftop solar system is frequently sold, providing useful information regarding demand-side management.

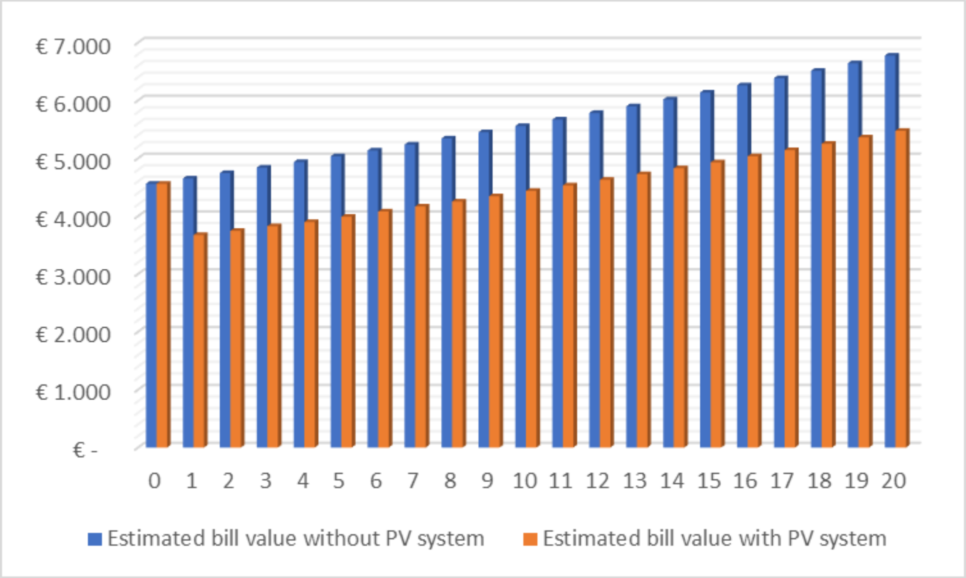
Figure 5-8: July - Energy balance Typical weekday and weekend day



(Source: Author)

Finally, a comparison between the annual electricity bills with and without a PV system is provided (Figure 5-9). For people who are looking for savings in terms of money, the expected investment cost and the yearly savings can be analysed in order to decide if this project reaches their financial expectations.

Figure 5-9: Annual electricity bill value.



Source: (Statista, 2021b)

In general, based on the LCOE and the expected values for the feed-in tariff, the most beneficial installed capacity in the residential sector for average households is around 3kW, bigger systems would increase the percentage of sold energy. From a financial point of view, this is undesirable because the LCOE is higher than the feed-in tariff. In any case, the use of the tool could lead to a better understanding of every particular case.

In the farming sector, it makes no sense to present an average recommended installed capacity, since the energy demand in the farms is in a big range. On the other hand, farms have bigger electricity demand in comparison with the residential sector, and in most cases, bigger roof areas. These two factors create the appropriate conditions to take advantage of bigger rooftop solar systems, but the size of the system should be carefully selected aiming to consume as much as possible the generated energy.

5.2.3 Anaerobic Digester Design for Farms

As mentioned, focus of the study is on farm level anaerobic digestion system. The following steps were followed by the team during the international class:

- The present waste management practice in the farms were assessed in detail and the view and understanding of anaerobic digestion technologies in the farm were analysed.
- A model in excel was developed to calculate different parameters of the biogas production in small scale. More details of the model are explained further in this report.
- After the creation of the model three scenarios were selected to make an analysis of the results for small scale biogas.

Analysing Farm level biogas systems

A major attraction of AD system is the associated multiple revenue streams (World Biogas Association, 2019), the possibility of which was analysed during the course of the study in the farms of Loop Head. For this study, the possibility of three different end uses on a farm level have been analysed which include direct thermal application, electricity generation and biomethane upgradation. However, biomethane upgradation has technical and financial limitations. Gas upgradation technology require considerably higher rates of gas generation and have higher investment and operation costs. Only systems with gas generation of over 100Nm3/hr can be deemed technically feasible for an upgraded biomethane end use (IRENA, 2013). Also, to maintain a financial viability the selection of waste mixture needs to be done such that maximum biogas can be generated from the same digester volume. Small scale digester could be an appropriate technology for the management of waste generated on a farm. Thus, this study focuses on the possibility of intervention of such technologies for the farms in Loop Head.

The operating temperatures

Optimum anaerobic digestion process takes place in Mesophilic (35-40°C) and Thermophilic (55-60°C) temperature ranges. Though reaction rates also occur in ambient temperature ranges, the low temperature averages make it unfeasible for the case Loop Head. Hence mandating the need to maintain the either mesophilic or thermophilic range. This requires the need of a digester heating system to ensure that the reaction inside the digester is maintained at the required rates. The heating requirements can be supplied by the use of the self-generated biogas, consuming 10-20% (XD Consulting, 2020) of the energy generated depending on the type of operating conditions. In the mesophilic range the hydraulic retention time (HRT) is estimated at 25 days and 10 days for thermophilic (Environmental Science and Engineering Magazine, 2020). The change in the HRT reduces the digester volume by almost 60% resulting in substantial decrease in the investment costs. But a major trade-off is brought by the increased operational cost. Hence selection of the operation temperature is one of the most important part of the process and is also defined by the rate at which waste is generated and the anticipated end use.

Biogas tool for pre-feasibility of farm-scale AD systems

To analyse the pre-feasibility of an individual farm scale biogas digester in Loop Head, an Excel based tool was developed over the course of the study. The tool provides a platform for any farmer to assess the potential of generation of biogas and energy with inputs of the waste available in the farm. The tool also provides an estimate on the investment costs, annual operating costs, and expected earning/savings in terms of the revenue generated from the farm. The tool has been incorporated in the final model developed by the study and the manual for its use has been provided along with this report.

An average cattle housing in Ireland is estimated at of 121 days in dairy farms (Buckley, 2020). Similar trend is observed in Loop Head. Assuming this and considering a factor of safety for the collection rates, only 20% of the produced manure has been assumed to be available for the generation of the biogas by the tool. The value concur with the assumptions by (Sean O'Connor et al., 2020). The biogas yield from cattle manure is comparatively lower than other sources such as agriculture residue or even household organic waste. Hence co-digestion is a common practice opted by farms to increase the biogas production even with the same plant size and is recommended by the tool.

The developed model was run for three farms in Loop Head covering both small and large farms in the region. The following output were obtained under different scenarios. Farm A housing 25 cattle, farm B with 102 and farm C with 320 cattle were considered for the analysis and also for the test the tool for any bugs. Important parameters under different end use case have been presented in the Table 5-4. From the input provided regarding the number of cattle in the farm, the tool also estimates the amount of silage requirement for an optimal gas generation keeping in consideration both technical and financial parameters. The calculation is based on the use of the co-digestate. However, the user also has the option to opt for calculation with only the cattle manure.

Table 5-4: Comparison of AD operational parameters

Total Number of Cows	**25**	**102**	**320**
Total waste per day (kg/day)	375.00	1,530.00	4,800.00
Suitable silage requirement (kg/day)	650.00 (12.99 ha)	2,650.00 (55.54 ha)	8,300.00 (173.97 ha)
Daily Biogas Production (m3/day)	85.99	350.82	1,100.62
Total Input Feed (kg/day)	2,738.54	11,173.00	35,053.29
Water Requirement (litre per day)	1,713.66	6,991.74	21,934.89
Compost Generation (kg/day)	370.71	1,512.49	4,745.08
Digester Volume (m3) mesophilic	68.46	279.33	876.33
Digester Volume (m3) thermophilic	27.39	111.73	350.33

Source: Author

The figures illustrate the wide range of AD systems that fall under the individual-farm level biogas in Loop Head. Though the tool does not define specific technology for biogas production, a single technology will not be applicable for such large range and hence the best technology needs to be identified for each farm size or the technology needs to be optimized based on the waste volume. Also as mentioned above the decrease in the digester volume in thermophilic operation range as a result of decreased HRT can also be observed.

The following tables detail the energy and financial outputs of the three sample cases. The thermal parameters are available in Table 5-5. Economies of scale play a substantial role in the investment and operations of costs of a biogas plant. Hence the limitations of the tool regarding financial estimation can be observed. The investment costs are predicted based on a cost curve derived from regional AD system prices that were acquired from regional companies. However, as only limited regional data could be acquired for limited size range of AD systems, the cost curve is not able to give exact figures on the investment. Also, these values were observed to be slightly higher than the global average values, but nevertheless regional values were prioritized over global. Also, the investment costs are specific to technology in use and the service provider. Hence the tool is only able to provide a tentative cost and further detailed financial analysis is recommended. The investment cost of 2.5 M€ Euros for the Farm C is staggeringly high and investment on it in the absence of any financial support or grant may not be feasible on an individual level. The Operations and Maintenance costs are more realistic. The thermal energy potential is calculated assuming the combustion of the gas in a boiler. The revenue in the thermal case, provide a monetary value to the gas produced rather than direct inflow of cash.

Table 5-5: Thermal end-use

Thermal	**Operational Temperature**	**25**	**102**	**320**
Thermal Energy Potential (kWh/day)	**N/A**	371.45	1,515.54	4,754.66
Total Investment Cost (Euros)	**mesophilic**	243,290.73	464,560.31	2,527,345.40
	Thermophilic	231,565.10	269,370.82	606,218.57
Total annual operational cost (Euros/Year)	**mesophilic**	2,999.00	12,237.16	38,391.09
	Thermophilic	4,393.35	17,924.88	56,234.90

Total Revenues (Euros/Year)	**N/A**	7,450.19	30,396.76	95,362.38

Source: Author

For electrical end use the electricity potential is calculated assuming that the produced biogas is used in a CHP engine to generate electricity and heat. The heat generated can be partly used for heating the digester or meeting the heating needs of the farm. As mentioned above the high investment costs here as well are based on regional values contributes to making the project financially unsuitable without support. The revenues are calculated based on a feed in tariff of 0.14Euros/kWh which was determined as an average cost in the region as per community discussions, but the tool provides an option to change the tariff rates.

Table 5-6: Electrical end-use

Electrical	**Operational Temperature**	**25**	**102**	**320**
Electrical Energy Potential (kWh/day)	**N/A**	139.30	568.33	1,783.00
Total Investment Cost (Euros) (Inclusive of CHP)	**mesophilic**	247,585.00	482,083.83	2,582,321.17
	Thermophilic	235,860.00	286,894.35	661,194.34
Total annual operational cost (Euros/Year)	**mesophilic**	3,956.97	16,144.43	50,649.20
	Thermophilic	5,351.02	21,832.15	68,493.01
Total Revenues (Euros/Year)	**N/A**	10,500.78	42,843.20	134,410.04

Source: Author

For the biomethane upgradation end use option, the tool does not permit it for plants with less than 100 cattle due to technical restrictions of the technology. The upgradation process requires higher gas flow rates. Also, high financial investments and considerable operations and maintenance cost make the technology unfeasible for application on a farm-scale biogas plant. Even though a wide variety of end use applications are possible from upgradation to Renewable Natural Gas (RNG), the study would not recommend the technology for farms in Loop Head.

Table 5-7: Biomethane Upgradation end-use

Biomethane Upgradation	**Operational Temperature**	**25**	**102**	**320**
RNG Energy Potential (kWh/day)	**N/A**	-	1,760.81	5,524.10
Total Investment Cost (Euros)	**mesophilic**	-	541,168.00	2,767,683.24
	Thermophilic	-	345,978.00	846,556.42
Total annual operational cost (Euros/Year)	**mesophilic**	-	35,999.63	112,940.00
	Thermophilic	-	41,687.34	130,783.82
Total Revenues (Euros/Year)	**N/A**	-	49,008.32	153,751.60

Source: Author

Results and Recommendations

The use of AD in developed countries has been observed to incline towards managing of waste and treatment of high COD waste as opposed to the focus on energy generation in developing countries (frontiers in Energy Research, 2014). A potential farm system for Loop Head would cover both aspects and provide a leap towards circularity and sustainability. The technology has showed technical feasibility for varying farm sizes with potential for substantial energy generation to meet the demand of the farms. However high investment cost is seen as a primary hindrance even though the generated revenues are considerable to meet the operational costs. Though a minimum of 300 cattle threshold is estimated as a requirement for electrical end-use of biogas to be feasible on farm level (The Minnesota Project, 2014), CHP is also seen as a possibility for farms in the peninsula.

The results of the three sample farm types showed significant potential in terms of energy generation in the farms. Regarding electricity produced this would be able to cover the entire electricity demand of the farm if used a base load. The avoided environmental impact through the abatement of CO2 emissions is another benefit. However, implementing on a farm level, even with reasonable revenue generation did not deem the system financially feasible due to the high investment costs. Even though the financial performance can be improved with the use of specific technology and region-specific values, obtaining a reasonable payback period seems less likely. Some suggestion and recommendations have been put together for making individual-farm scale biogas more attractive for Loop Head.

- Primarily a support scheme would be required to roll out the biogas industry in the community. This could be done through the support and initiation of the authoritative body, but also with active participation of the local community (farmers) (Irish bioenerby association, 2019).
- Investment costs can be further reduced if high level of interest can be generated in the community, creating a market for the service providers.
- The high initial investment costs make the realization of the project highly impossible. However the Irish Bioenergy Association recommend the possibility of subsidy of up to 40-50% which would provide a more favourable financial parameters (Irish Bioenergy Association and Composting and Anaerobic Digestion of Ireland, 2019). With these subsidy rates the tool showed a possible payback period between 10-15 years. The approach of using carbon taxes to fund AD projects has been suggested.

- Another approach to reduce the investment costs could be through the introduction of low interest loan schemes for potential AD owners.
- The digestate post AD process provides a good opportunity for revenue generation. However the tool calculates the revenue at minimal costs of 0.025 Euros/kg (XD Consulting, 2020). Better market for the fertilizer can be identified with improved rates. 10-fold higher fertilizer price were also observed during the research of the study in other parts of the world.
- In case of electricity generation improved feed in tariff or incentives for generators could be an approach that can be implemented on a community level.
- Though biomethane upgradation was not deemed feasible in the earlier section, the future expansion of natural gas grid in Loop Head or the initiation of district heating could provide opportunity for gas upgrading. The tool estimates the revenue of biomethane based on natural gas prices (0.03 Euros/kWh) (Irish Bioenergy Association and Composting and Anaerobic Digestion of Ireland, 2019), but its application in the transportation sector could provide more profitable opportunities and thus can be further looked into. To make the biomethane end use more feasible the Irish Bioenergy Association has also suggested the need for an additional 0.06 Euros/kWh to bridge the gap between the market rice of NG and the cost of production of biogas (Irish bioenerby association, 2019) . The difference in the price can be better covered based on the CO2 costs in the EU certification market.

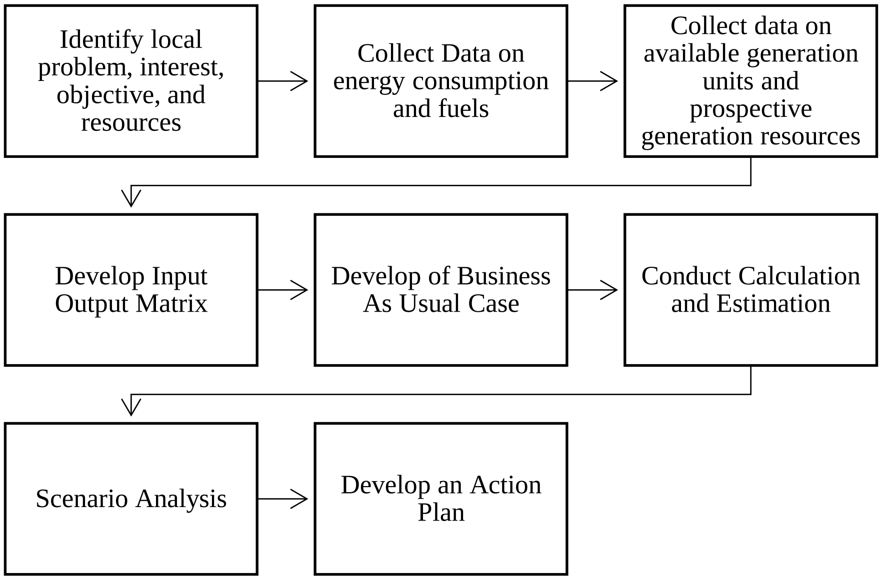
5.3 Conclusion

The transition of farms in Loop Head towards a circular economic model has been identified as the way forward to address issues concerning poor energy efficiency, fossil fuel dependence and mismanagement of cattle manure. The study focused on addressing each of these issues and provides point of initiation for the community towards circularity starting with a detailed energy audit is seen as the first steps to addressing the energy efficiency issues in the farms. Considering the high local interest in the technology, Solar PV systems were identified as the ideal technology for making the farms self-dependent on their energy generation. The larger roof areas of farms make the technology even more appealing. In addition, the increase in the efficiency and decrement in the price for solar panels during the last 10 years have allowed the economic viability of rooftop solar systems in Ireland. The tool developed over the course of the study determined an average payback period of 9 years, relatively attractive compared to general payback period of a renewable energy system. The possibility of managing the manure produced in the farms through the installation of farm scale anaerobic digesters was analysed. A tool to calculate the potential of biogas in the farms and estimate costs was developed during the study. Though the technology showed technical feasibility, the high investment costs made the technology may does not make it economically attractive. Hence without incentives implementing the technology on a farm level would be difficult. All in all, switching to a circular economic model could be beneficial for the sector and could contribute toward the Irish vision of long-term low carbo economic system.

6 Community Energy Modelling

A community's initiative to promote and establish sustainable energy system necessitates thorough analysis of the local energy system - assessment of community's energy demand and energy production potential. Besides, identification of suitable generation technologies, willingness of the community to invest in those technologies, and polices to support the development of sustainable energy system in the community play an important role to shape the community's future energy system. Based on the requirement, community energy modelling can be performed to integrate these factors for supporting investment decision as well as assessing scenarios to plan for the strategic development of energy system.

The process of community energy modelling involves number of steps starting from identification of the local problem, interest, objectives and financial resource identification. To identify the correct strategy, modelling process involves further steps like data collection, estimation, and calculation, see Figure 6-1, (PlanEnergi, 2010). Each of these steps require inputs data on the community which can be collected via interviews, questionnaires, or statistical records. The data collected are then processed to estimate the economic solution for the community energy system.



Source: (PlanEnergi, 2010)

Figure 6-1: Process of Community Energy Modelling

6.1 Energy Modelling for Loop Head Community

In order to support Loop Head's initiative to establish a sustainable energy system in the peninsula, an interactive energy modelling tool, IC Model 2021, was developed in Microsoft Excel. The tool was developed with an objective to provide the basis for investment decisions, support operational decisions, and serve as a platform for different stakeholders to analyse different scenarios, see Figure 6-2.

(Source: Author)

Figure 6-2: The purpose of Loop Head Energy Model

The model aims to provide an overall outlook of the Loop Head energy by integrating following information:

i. individual energy demand of each energy consuming sectors (residential, farming, and commercial)
ii. possible globally proven renewable energy generation technologies in the peninsula, associated technical parameters, generation pattern of each technology, and associated cost of each technology
iii. existing policies in the peninsula

Besides the possibility to analyse entire energy system in Loop Head, the model also targets to assist individual community members: residential households and farms to identify suitable solution to achieve energy sustainability. To address this, the model includes individual worksheets on the Excel model where interested stakeholders can provide inputs and analyse the scenario.

The excel model developed by IC 2021 is an expansion of the model developed by IC 2020 which was initiated to identify possible improvement opportunities and apply those improvements. IC Model 2021 has been designed for Loop Head in compliance with CRaFT model: consistency, robustness, flexibility, and transparency as suggested by Liam Bastick (Liam Bastick, 2018). Subjecting the IC 2020's model to Craft criteria, improvement opportunities, listed in Table 6-1 were observed and addressed in 2021's model

Firstly, as promised by the CRaFT model, the consistency of the excel model has been developed such that it is easily understandable by users once they become familiar with both the model's purpose and content. Secondly, based on the mathematical accuracy and absence of errors, the model's robustness has been ensured and verified by IC 2021 groups internally and the potential users from the Loop Head community. Further, to enable the flexibility of the model, the model is designed in such a way that it can change various assumptions or input parameters to see how the changes affect various outputs. Lastly, by including sources of data used, the transparency of the model has been ensured.

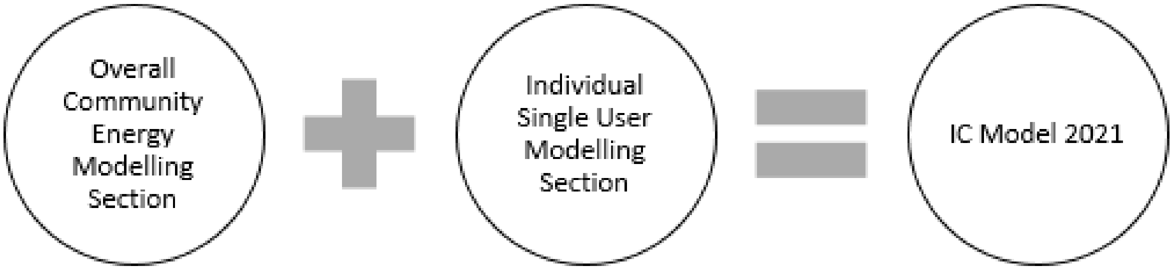
Table 6-1: Additional features IC 2021 Model

Topic	**IC 2021**
Key Performance Indicators (KPI's)	Includes KPIs such as: Levelized cost of energy, cost of the specific energy system, the share of renewable energy, and financial parameters such as Internal Rate of Return (IRR), and payback period
Visualization	Graphical and user interactive model
Flexibility	Provides the flexibility to adapt new assumptions and conditions on generation, demand, tariff, grants, population, households, efficiency of technologies, investment cost, population of cattle.

Data Resolution	Capable to show hourly variation in the system electricity demand, generation, CO_2 emission, and electricity imported from grid.
Energy Storage	Adapts to see the system response with incorporation of battery storage in the system
Variability of Solar and Wind Energy	Hourly resolution of solar and wind generation in the peninsula is incorporated
Model Structure	Easy Operation and visually easy to understand

6.2 Excel Modelling Tool Development

The IC Model 2021, an interactive energy model designed for Loop Head community, provides a platform for the users to understand the status quo of existing energy system in Loop Head whilst providing the flexibility to integrate renewable energy technologies and study the effect of integrating such technologies to the overall energy system of the peninsula. Simultaneously, this model also provides additional interface for interested individual users from residential and farming sector to understand and analyse the methods and financial benefits of adopting energy efficiency measures in residential households and installing renewable energy technologies in farms. The development of this model, therefore, can be broadly categorized into two sections (Figure 6-3).



(Source: Author)

Figure 6-3: Sections of IC Model 2021

i. Overall Community Energy Modelling section

The overall community energy model section focuses on providing information on the entire energy system of the peninsula. This includes information related to the sectoral energy demand, necessary energy imports, CO_2 emissions, energy generation prospects from installation of renewable energy technology, energy efficiency method of residential sector, and the associated costs. Besides, it also provides the possibility to analyse the effect of implementation of policy measures in the peninsula in terms of grants and feed-in tariff. The section provides the possibility to study the hourly operation of electricity sector in the peninsula in terms of electricity demand, imports, generation, and CO_2 emissions.

ii. Individual Single User Modelling section

The individual single user modelling section, which is also incorporated in the IC Model 2021, will provide three interfaces for the individual users to analyse on listed topics:

a. energy efficiency measures in residential buildings
b. PV installation in residential building and/or farms
c. anaerobic digester in farms

The individual users who wish to have a detailed knowledge on application of energy efficiency measures in the residential sectors can directly use the related interface in IC Model 2021 and obtain the information on the retrofitting measures, cost of building retrofitting, and percentage of energy saved from applying the retrofitting measures.

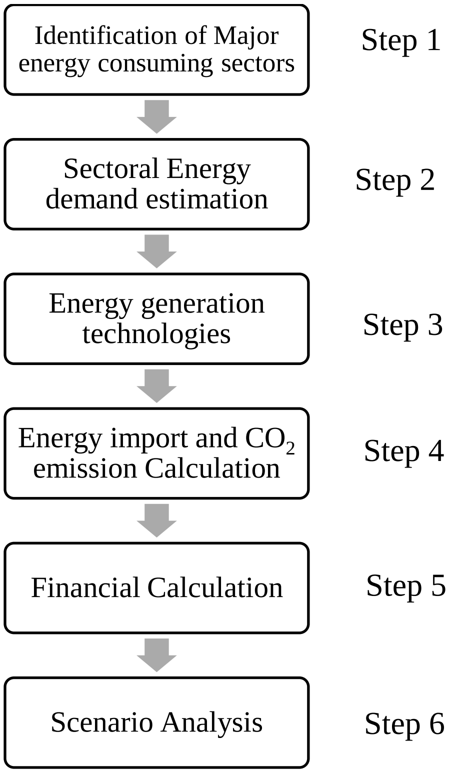
Similarly, in the interface related with the PV installation, the interested users can find information for fitting optimal size of solar PV systems in their residential buildings and/or farms and calculate the costs associated with it.

In the third interface, which is related only to farms, interested users can estimate the size of anaerobic digesters for their farms whilst also calculating the associated investment and operation costs for the digester system.

The methodology for development of each of these individual interface and related calculation are detailed in Chapter 5.2.2.

6.3 Methodology for Overall Community Energy Model Development

Figure 6-4 presents the methodology adopted for developing overall community energy model section in IC Model 2021.



(Source: Author)

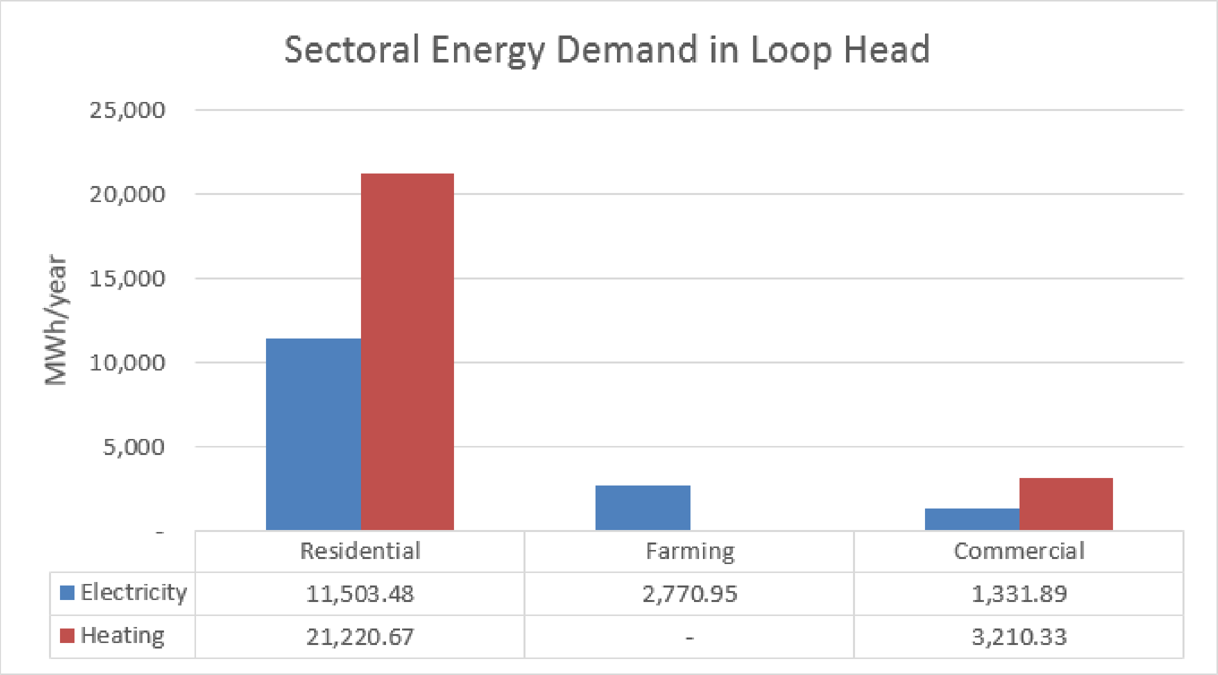
Figure 6-4: Conceptual Framework for Community Energy Model Development

6.3.1 Identification of Major Energy Consuming Sectors and Demand Estimation

Three major energy consuming sectors i) Residential Sector ii) Farming Sector, and iii) Commercial Sector were identified in Loop Head peninsula. The total annual energy demand in Loop Head, which comprises electricity and heat demand was calculated separately for each of these sectors and integrated in the model. For calculating total electricity and heat demand in Loop Head, equation 4-1 was considered.

$$Total\ Energy\ Demand = Final\ Energy\ Intensity * Activity\ Level \tag{6-1}$$

The total annual sectoral demand of each of the sector was calculated by identifying the final energy intensity and activity level associated with each of these sectors. The total annual energy demand in the Loop Head was calculated to be 40,037.32 MWh/y, see Figure 6-5.



(Source: Author)

Figure 6-5: Sectoral Energy Demand in Loop Head

Residential Sector Energy Demand

The total residential energy demand in the Loop Head, which comprises electricity and heat demands was calculated separately and integrated in the model.

i) Electricity Demand in Residential Sector:

The total electricity demand by the residential sector is approximately 11.50 GWh. The estimation of total electricity demand was done using equation **Error! Reference source not found.**, where t he average per capita residential electricity consumption of Ireland (1.72 MWh/a) was used as the final energy intensity of the residential sector in Loop Head (SEAI, 2016a). Similarly, average household size, obtained from Central Statistics Office (CSO, 2018) for each electoral division was considered as the activity level.

$$\begin{aligned}&\mathit{Residential\ Sector\ Electicity\ demand}\\&\qquad= \sum (\mathit{average\ household\ electricty\ demand\ x\ household\ size}\end{aligned}$$

ii) Heat Demand in Residential Sector:

The total heat demand in Loop Head is about 24.4GWh. This is divided into space heating and water heating demand in residential and commercial sectors. According to the heat demand atlas of the Sustainable energy Authority of Ireland (SEAI, 2018b), the total heat demand for the residential sector comprising the 10 electoral districts making up the loop is 18.74 GWh separated into space heating and water heating. The total space heating demand estimate for the residential sector is 16.9 GWh and the total water heating demand is 1.82 GWh. According to the 2018 final energy end use estimate by SEAI, the space heating and water heating per capita for Ireland are 4.098 MWh/y and 1.29 MWh/y. This shows that the current heating demand in the loop is higher than the national average based on the resident population and the number of occupied houses on the Loop Head. Therefore, heat demand per household has been estimated based on the national average heat demand and the excess demand in the residential sector is assumed to be the demand of the 1,590 holiday homes in the Loop Head. With this assumption, the total heat demand per holiday house is 2.73 MWh/y.

iii) Heat saving from retrofitting:

From the cost curve, as described in Chapter 4.1.4, a best-fit third-degree polynomial equation was approximated to estimate the cumulative cost of retrofitting for every percentage of heat saved from implementing retrofitting measures.

$$y = 213.8x^3 - 80.7x^2 + 22.8x$$

where y = Cumulative retrofitting cost in Euros; x = Heating saving in percentage of total heat demand in MWh.

Farming Sector Electricity Demand

The Loop Head's farming sector consumes, approximately 2,770 MWh of electricity on annual basis. For calculating the Farming Sector's electricity demand, the farming sector was divided into three subcategories: i) small dairy farms, ii) large dairy farms, and iii) beef farm. For each type of farm, the average electricity required by the cattle type in respective farm was considered as the final energy intensity and the total number of the cattle in those categories of farm in the peninsula was considered as the activity level. While the average electricity consumption was calculated based on interviews, the total number of dairy cows and beef cattle in the peninsula was based on the statistical records obtained from CSO. The detail calculation of the farming sector's electricity demand is described in Chapter 5.2.2.

Commercial Sector Energy Demand

i) Electricity Demand in Commercial Sector

The total commercial electricity demand on the Loop Head is about 1.3 GWh. The commercial sector electricity demand comprises of the total estimated electricity demand by the five hotels on the Loop Head with annual electricity demand of each hotel room to be 12.56 MWh/y (EUF, 2020). This annual electricity intensity of each hotel room is considered as the final energy intensity and the number of hotel rooms in the Loop Head peninsula, i.e. 106, was considered as the activity level. The value seems high for a room of a hotel, however, due to unavailability of updated data and the limitation to validate the existing data, same old information from IC 2020 report has been adopted. It is highly recommended to validate and use updated data in the model.

ii) Heat Demand in Commercial Sector

The total commercial heat demand on Loop Head is about 3.2 GWh (SEAI, 2018b). The commercial sector heat demand consists of the total estimated heat demand by the five hotels on the Loop Head was 0.715 GWh/y (EUF, 2020), and heat demand by Water World and other shops, offices etc. was 2.49 GWh/y. The estimated average heat demand per hotel room is estimated to be 6.75 MWh/y, this value is considered as the final energy intensity for hotel consumption and total number of hotel rooms taken as the activity level.

6.3.2 Hourly Electricity Demand Profile of Different Sectors

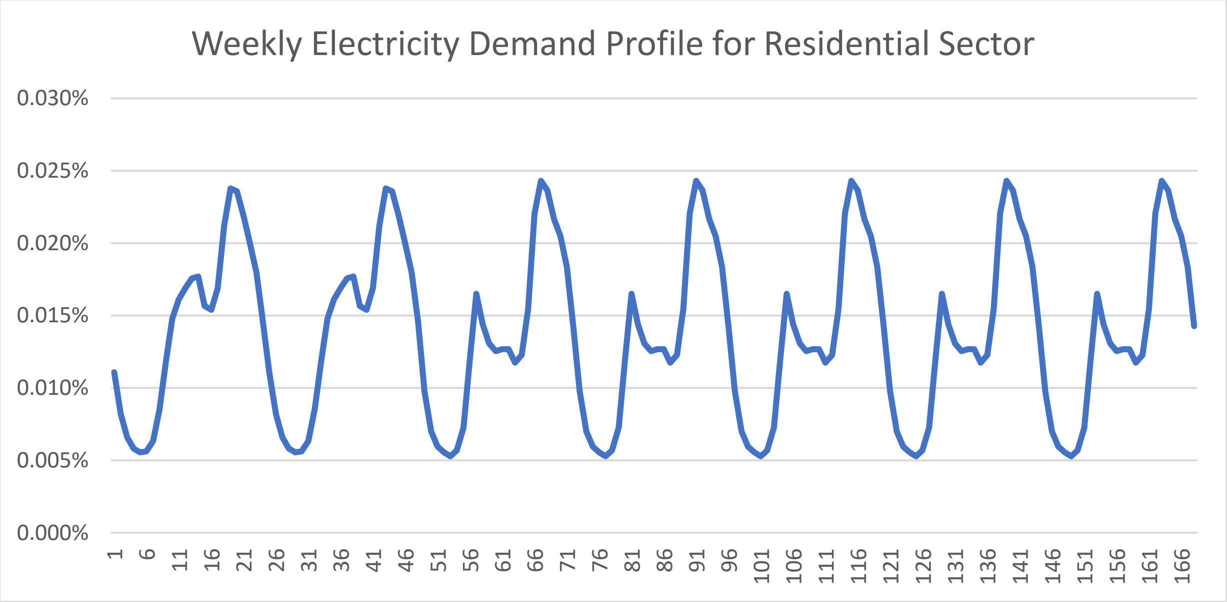
The study for the transformation to entire renewable energy-based power system requires detailed assessment of the load profile and the available renewable energy sources. Integrating the potential renewable energy sources, mostly wind and solar, introduces the challenge of intermittency. Often, for an uninterrupted supply, the intermittent behaviour of these available resources requires to be matched with the time varying power consumption of the region, i.e. the load profile. This enables the operators to increase system's reliability and optimize the system cost by addressing subjects of concern on how to: operate the system, size the storage requirements, maintain the system stability, and curtail the surplus energy. To address these subjects, analysis of load profile and identification of following situations are crucial (IRENA, 2018, p. 10)

i. Minimum level of load in the system and frequency of its occurrence.
ii. Times of the day where there is sharp increase or decrease if the load.

In order to assess the situation, load profile with higher resolution (containing at least the hourly variations of the load) is preferred. Higher resolution of the load profile aids better flexibility of the generation units for system operation (IRENA, 2018). Usually, the best available data on load profile are the recorded data from the system operators. However, in the absence of the real load profiles for the community, synthetic load profiles can be generated based on a standard load profile of the country.

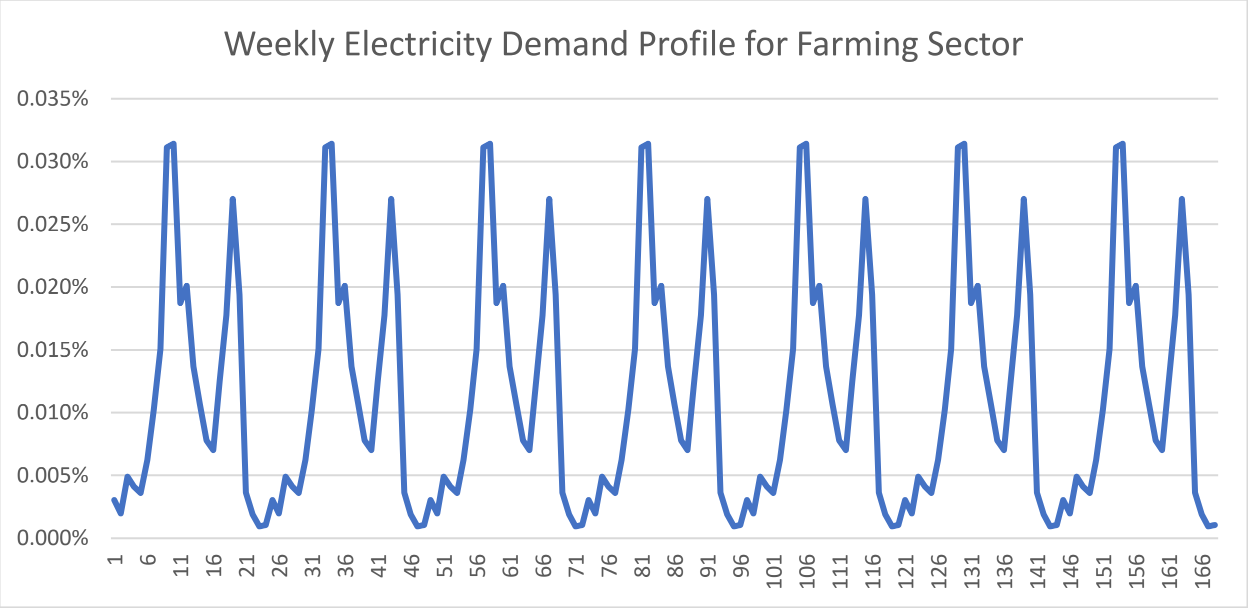
In case of the Loop Head community, the sectoral load profiles were not easily available. Besides, limited time for IC 2021 challenged the possibility to conduct a survey and synthesize a load profile for each sector in the peninsula. Therefore, synthetic load profile was developed based on literature available for Ireland, as detailed in Chapter 4.2.1 (Ricardo, 2020, pp. 124–125). Similarly, the load profile seen in Figure 6-7 for the farming sector was synthesized based on energy demand profile generated for farms in Ireland (J. Upton et.al, 2013, p. 6). The details on the hourly demand synthesis for farms is explained in Chapter 5.2.2. The hourly demand profile for the commercial sector in the Loop Head was synthetically generated with similar climatic condition as in the Loop Head. This hourly demand profile was synthesized from HOMER, a power system design and optimization software. Due to absence of student groups working on the commercial sector in IC 2021, and relatively smaller energy demand of the commercial sector, this approach was expected to approximate the commercial hourly demand profile for the Loop Head. The hourly profile of the commercial sector can be seen in Figure 6-8.

The model also provides the flexibility to change these hourly demand profile of each sector.



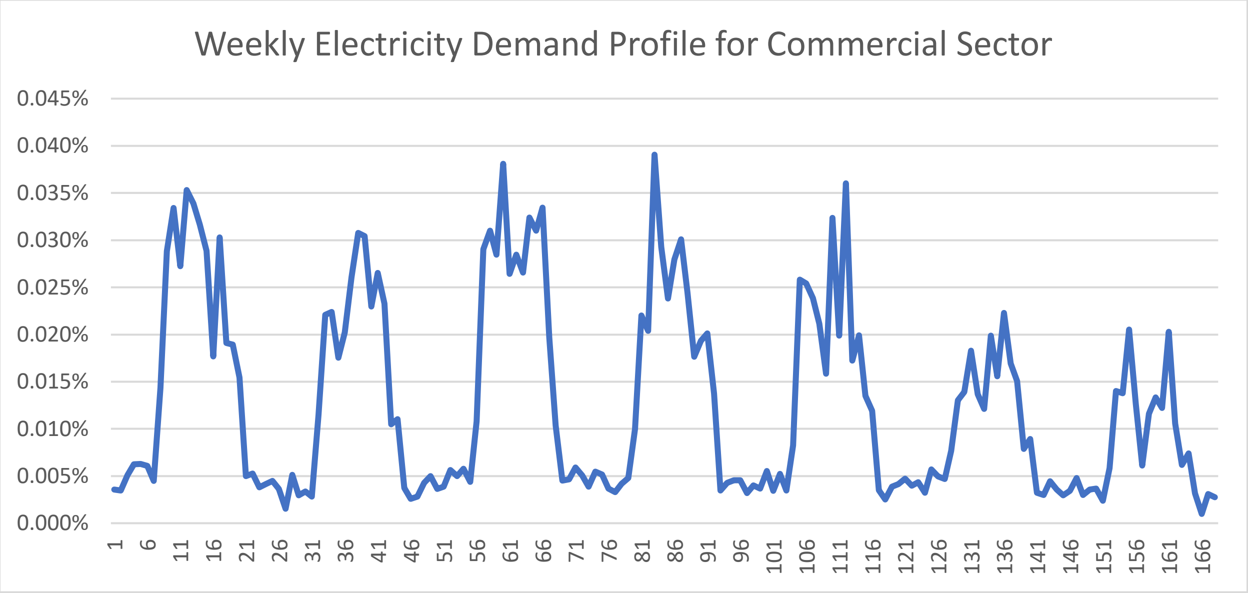
Source: Synthesized based on (Ricardo, 2020, pp. 124–125)

Figure 6-6: Hourly Electricity Demand Profile for Residential Sector for a Week



Source: Synthesized based on (J. Upton et.al, 2013, p. 6)

Figure 6-7: Hourly Electricity demand Profile for Farming for a Week



Source: Synthesized from HOMER energy software

Figure 6-8: Hourly Electricity Demand Profile for Commercial sector for a Week

6.3.3 Generation Technologies

Solar and wind are the globally proven and widely implemented technologies and requires less resources for formulation. Hence, these technologies were considered as the two renewable energy technologies which could be swiftly implemented in the Loop Head peninsula to supply the internal demand of the peninsula. In case of solar technologies, the model provides the possibility to incorporate a variety of solar systems into the Loop Head energy system, ranging from small roof top solar in the individual households and farms to large scale solar plants which could be installed by the community. In case of wind technology, the model provides the option to study the effect of incorporating relatively large-scale community wind farms to the peninsula's energy system.

In order to calculate the energy generation from each of these technologies, certain technical and financial parameters associated with the respective technologies has been assumed. These assumptions will be discussed in detail in the following sub-chapters.

Solar Energy

In order to calculate the solar energy generation possibilities in Loop Head, reference values for the hourly electricity production which would be made by a 1 MWp solar plant installed in Kilkee was considered. These values were based on MERRA2 dataset at a latitude of 52.62^0N and 9.72^0W longitude at a tilt angle of 39^0 (Pfenninger et. al, 2016). Besides, listed assumption on the technical parameter (Table 6-2) and financial parameter (

Table 6-3) were made for detailed calculation of production possibilities from each type of solar system and for calculating the total cost, which would incur for the respective type of the system.

The model also provides the flexibility to change the hourly generation profile and assumptions made on the technical and financial parameters.

Table 6-2: Technical Parameters for PV system

Technical Parameters	
Ground Mounted PV System Area requirement	40 m^2/kWp
Roof -Top Solar System Area Requirement	10 m^2/kWp
Optimal Tilt Angle	39^0

Module Efficiency	18%
Performance Ratio	80%

Table 6-3: Financial Parameters for PV system

Financial Parameters				
Type of PV System	**Investment cost [€/kW]**	**O & M Cost [€/kW/a]**	**Lifetime [Year]**	**Discount Rate (%)**
PV Community	1000	10	20	3.5 %
PV Farm	1200	5	20	3.5 %
Rooftop PV in Residential household	1200	5	20	3.5 %
Rooftop PV Hotels	1200	5	20	3.5 %
Small Battery (per kWh)	500	5	10	3.5 %

The details on the cost associated will be discussed in Chapter 6.3.5

Wind Energy

In order to calculate the wind energy generation possibilities in Loop Head, reference values for the hourly wind speed data have been utilized at a hub height of 60 m to calculate the hourly electricity production. These hourly wind speed values were obtained from MERRA2 dataset at a latitude of 52.62^{0}N and 9.72^{0}W longitude (Staffell et.al, 2016). Besides, listed assumption on the technical parameter (Table 6-4) and financial parameter (Table 6-5) were made for detailed calculation of production possibilities from the community wind farms.

The model also provides the flexibility to change the hourly generation profile and assumptions made on the technical and financial parameters.

Table 6-4: Technical Parameters for Wind Farm

Technical Parameters		Remarks
Hub Height	60 m	Values can be changed in the model by the user based on detailed design
Coefficient of Roughness	0.1 m	Values can be changed in the model by the user based on updated resources.
Wind Park Efficiency	50%	Values can be changed in the model based by the user based on detailed design
Land Area Requirement	0.24 km^2	Values can be changed in the model by the user based on detailed design

Table 6-5: Financial Parameters for Wind Farm

Financial Parameters				
Type of PV System	**Investment cost [€/kW]**	**O & M Cost [€/kW/a]**	**Lifetime [Year]**	**Discount Rate (%)**
Wind Farm	1500	35	20	3.5 %

6.3.4 CO2 Emission Calculation from Imported Electricity

CO_2 Emission from Imported Electricity

CO_2 emission caused by imported electricity in Loop Head can be estimated given there is information available on the share of fuel mix present in the imported electricity. Since, electricity import in Loop Head is made through the national grid in Ireland, share of fuel mix present in the imported electricity is difficult to calculate. Therefore, the share of fuel mix present in the imported electricity was assumed to be equal to the national hourly generation mix.

Electricity generating in Ireland is based on coal, natural gas, wind, hydropower, biogas, and biomass. Out of these, coal and natural gas are the major contributors of CO_2 emission in the electricity supply sector.

Firstly, to calculate the share of fuel mix in the electricity demand, it was assumed that for each hour of the year the generation from base load Moneypoint Power station (915 MW), coal fired plant remains constant. For the calculation of CO_2 emission, the efficiency of this plant was calculated to be 38.05%, based on the energy balance of 2015 (IEA, 2017). The remaining residual demand is then supposed to be supplied by the available hourly wind generation. In the case the demand is not supplied by the coal and wind power generation, it is considered as covered by the natural gas generation. An average efficiency of the natural gas power plant is taken as 50% for calculation of CO_2 emission. Based on this assumption, the hourly contribution of each type of generation to the demand was calculated and was applied to calculate the share of fuel mix in electricity import in Loop Head. This share of fuel mix was then utilized to calculate the CO_2 emissions considering emissions of 0.3406 tCO_2/MWh of fuel from Coal and 0.2047 tCO_2/MWh of fuel from Natural Gas (SEAI, 2021b). The result is an hourly time series of CO_2-emissions from imported electricity. The benefit from exported electricity is a reduction of gas-based generation and the associated CO_2-generation.

6.3.5 Financial Calculation Assumptions

The financial calculation involves various associated cost values and calculations. This section details the cost, which have been assumed as inputs to the IC Model 2021 for financial calculations. However, considering the possibilities of these costs to change over the time, the model provides the possibility for the user to change these values.

Investment and O&M Cost Technologies

The total investment cost accounts for the investment costs incurred from all the generation technologies which are added to the energy system. Investment costs and O&M costs listed in Table 6-4 are considered for the different technologies which can be added to the energy systems of the peninsula.

Fuel Cost

Following retail cost of fuels have been considered for the financial calculations

Table 6-6 : Fuel Cost considered in IC Model 2021

Fuel	Euro/MWh	Source
Peat	11.3	(EUF, 2020)
Oil	74.1	(EUF, 2020)
Coal	57.4	(EUF, 2020)
LPG	119.3	(EUF, 2020)
Electricity (Retail Cost)	170	Interview
Other (Wood etc.)	72.1	(EUF, 2020)

Electricity Cost Calculation

As an approach for simplified calculation, the retail cost of 17 Euro/MWh has been considered as the cost of electricity import in the peninsula. The various utility service providers retail the electricity at various costs. Hence, an average retail price of 0.17 Euro/kWh has been considered. However, this value can be changed in the model by users according to prevailing retail cost of electricity at the time of analysis.

Specific Cost of Electricity

It is the cost of per unit of electricity generated or supplied by each technology in a year. For simplicity, the cost has not been levelized over the lifetime of the powerplants. The "cost per kWh used" is average cost of electricity for Loop Head after installing renewable energy resources.

Grants

Following grants available from SEAI have also been considered in the model.

Table 6-7: SEAI Solar Grants considered in IC Model 2021

Grant	Euro/HH	Source
SEAI Solar Grant 1-2 kWp	900	(SEAI, 2020d)

SEAI Solar Grant 3	2100	(SEAI, 2020d)
SEAI Solar Grant more than 4 kWp	2400	(SEAI, 2020d)
SEAI Grant for Battery	600	(SEAI, 2020d)

Average Cost of Electricity

The total investment cost for each technology is a product of installed capacity and unit investment cost per unit installed capacity.

$$Total\ Investment = Installed\ Capacity * Investment\ Cost\ per\ unit\ installed\ capacity$$

Annuity Cost is a fixed annual average breakdown cost of total investment cost spread over the project period.

$$Annuity = \frac{Interest\ Rate * Investment}{1 - (1 + Interest\ Rate)^{-Time\ Period}}$$

Operation and Maintenance cost is cost associated with operating and maintaining the power plants. This cost also includes the fuel cost if applicable.

The total annual cost for each technology is sum of Annuity and O&M cost.

$$Total\ annual\ cost_{Technology} = Annuity_{Technology} + O\&M\ cost_{Technology}$$

The Specific cost, as mentioned in the model this output panel, is cost incurred to generate unit kWh of energy from specific technology.

Average cost of electricity is calculated as,

$$Average\ unit\ cost\ of\ electricity = \frac{\sum Total\ Annual\ Cost_{Technology}}{Total\ Annual\ Energy\ Used}$$

Net spending on Energy

The net spending on Energy in Loop Head is the total estimated cost of energy resources on energy minus revenue from the export of excess electricity. This estimation is conditional to the choice selection by users depending on the option of the feed-in-tariff, whether there is a feed-in tariff or not, and whether or not to change the feed-in tariff from 6 cents/kWh. The current estimated net spending on energy on the loop is around 7 Million Euro, comprising the cost of heating fuel, cost of electricity import, and fuel cost for transportation.

6.4 Integration of Individual Single-User Modelling Section in IC Model 2021

Integration of individual single user modelling section was done in the IC Model 2021 in order to provide single tool which would provide both the functionality for modelling entire community energy system as well as the modelling of individual sectors. Based on the work division on the residential and farming sector, the individual Single-user Modelling section were developed by responsible individual groups.

The assumptions, data, and final calculations, and interface developed by the individual groups were added to the IC Model 2021 along with the overall community energy modelling section. Special attention was given to maintain consistency on data and assumptions interrelated with the overall community energy modelling section and individual single user modelling section. However, the relation between the overall community energy modelling section and individual single user modelling section is one directional and there are no possibilities to provide feedback from the overall community energy modelling section to the individual single user modelling section.

6.5 Challenges of Modelling

The development of IC Model 2021 provided both enriching and challenging experiences at the same time. The collaboration process takes three forms namely: collaboration with members of the Loop Head community, with other project members working in different sectors, and collaboration within the Model group members. All collaborations and carried out online and it was done with lots of coordination efforts. The project also has a constraint of time (4 weeks), which includes scope definition, project planning, model development, and result presentation.

Another major challenge faced by the model development is data collection. The online nature of the project, combined with the constraints of time and resources led to some limitations in the amount of data that can be collected, which ultimately led to more assumptions in the model. An example of this effect is the carry-over of the same assumption related to hotel room electricity demand from IC 2020. This is as a result of limited time and the number of people working on the project because there is no project team dedicated to the commercial and transport sectors. It is therefore advised that future work should focus on the validation of some of the data and assumptions in the energy model.

The presentation and user -interface of the model to members of the community who have limited knowledge of energy and other technical terms related to energy constitutes a major challenge.

6.6 Model Limitations

The model shows the status quo of the total energy demand in Loop Head and provides the platform to formulate scenarios related to energy demand, generation, energy efficiency, and finances. The model has been created in a flexible manner such that input parameters and assumptions that can influence output information are modifiable. Notwithstanding, some functional limitations have been identified. These identified limitations are either related to the capability of the model to fulfil its intended purpose or influence the accuracy of the result obtained. These identified limitations are listed:

- The model does not consider economies of scale in the calculation of cost for renewable energy technologies.
- The transport sector has not been extensively elaborated; therefore, the consumption of diesel and petrol has been lumped as fuel consumption and average fuel cost assumed.
- The model does not consider a dual tariff system in the calculation of electricity imports from the grid.
- Finally, there is no direct interconnection between individual and community model, as a result of that, model users cannot use a bottom-up approach in scenario formulation.

7 Community Engagement

As per the objectives, the workshops conducted by IC 2020 provided a platform and a starting point for this year’s study. In line to findings of the IC 2020 workshops, a seven-week course was specially designed for the Loop Head Community by LEAP. The training was led by Mr. John Aston with inputs from the University of Flensburg, Energy Academy, SEAI, Clare Local Development Company, NUI Galway, Limerick Institute of Technology, and the Bryden Centre. The course aimed to support the community to understand the terminologies, technical aspects and underlying economics of renewable energy and community opportunities. The main intention of this course was helping participants to develop their confidence in renewable energy discussion at an individual level and for the community. The intended outcomes of the workshop were:

- Understand the key concepts of energy.
- Know how mastering your energy supply can lead to improved local livelihoods and community.
- Be aware of the energy-cost cycle and possible interventions.
- Access and sharing of information and resources to affect useful change.
- Develop critical thinking of the individual and community on renewable energy technology.
- Enable community members to use the Loop Head Peninsula Energy Balance Model to examine the status quo and alternatives.
- Enable community members to develop the home and/or organization’s energy strategy and plan.

7.1 Community Workshops

The goal of the online workshop was to train the participants of the Workshop on various aspects of various aspects of community energy relevant to Loop Head. The workshop aimed to close the knowledge gap in terms of community energy and energy terminologies which was identified by IC 2020. This workshop offered a channel to facilitate the activities carried out under the IC 2021. Supporting the IC2021 team to connect their work with the community, allowing the students to interact and gather information for the studies being performed. This will also support participants to make informed energy decisions, on energy efficiency and renewable energy technology.

The IC2021 took part in four sessions on 22nd, 24th of February and 1st and 3rd of March. The details on the agenda of the workshop are listed in the Annexes. The training included the following topics:

- Concepts of energy audits
- Energy efficiency in buildings
- Introduction to circular economy
- Solar on individual farms
- Biogas and waste management
- Community energy planning and lessons learnt from previous IC projects.
- Introduction to the energy model

A brief overview of the topics discussed, and the main content presented during the sessions are shown in Table 7-1.

Table 7-1: Workshop content

Day	**Topic Discussed**	**Main Contents**
22nd February	Energy Auditing	Discuss where energy is consumed in the residential and farming sector. Discuss the process of energy auditing. How much does the average household consume?
	Energy Efficiency	Describe the current situation in Loop Head. Discuss the measures relating to retrofitting, building envelopes.
24th February	Circular Economy	Explain the idea of Circular Economy. Examples of a circular economy.

	Biogas and Waste management	The general concept of Biogas. What kind of waste can be used for biogas generation. How can waste be managed in individual farms?
	Solar in Individual Farms	Introduction to Solar PV system. Present the tool to calculate the optimum size of PV for individual farms
1st March	Community Energy in Loop Head	Discuss the objectives, progress, challenges of the Loop Head Energy Partnership to orient the Panelists.
	Community Energy in Applecross	Discuss the energy journey of the Applecross community.
	Community Energy in Shetland	Discuss the energy journey of the Unst community in Shetland.
3rd March	Introduction to Loop Head Energy Model	Introduction to Loop Head Energy Model. Training participants to develop scenarios.

The workshops were hosted by Mr. John Aston on the Zoom platform. Any interested individual from the community were able to join the meeting via a link or the meeting id number. The workshops session and discussion were jointly moderated by Rijan Shrestha and Sheikh Ahmed Tijan Bah.

7.2 Workshop Sessions and Discussion

Session 1

Date: Monday, 22nd February 2021

This was the first workshop conducted by the IC 2021. The workshop was done in presentation plenary discussion format. The presentation and discussion of the workshop were focused on the topic of Energy audit and Energy efficiency. The topic of energy audit was presented by Nicolas Oviedo and Carlos Epia. The topic of Energy efficiency was presented by Nazym Temirgaliyeva and Neda Ebadi. The session was held on the Zoom meeting platform and attended by 23 participants from the Loop Head community.

Energy Audit:

The main objective of the presentation on Energy Audit was to orient the participants on the idea of the energy audit. The focus of the presentation was to:

- Introduce the concept of Energy Audit.
- Explain the type of energy audits and how energy audit is performed.
- Pre-site visit: Energy consumption and benchmarking.
- Present some energy conservation measures for the residential sector.
- Energy conservation recommendations for the dairy sector

An introduction to Energy Audit was provided by Nicolas Oviedo. Different stages of an energy audit, levels of an energy audit, and who can conduct an energy audit was explained. The time required to consume 1 kWh for general household appliances, electric shower, cooker, kettle etc. was shared along with the residential profile. This was done to visualize the daily load variations based on various residential activities. Outputs of energy audits, such as analysis and evaluation on current energy use and a list of recommendations to improve energy efficiency were shared. National Agricultural Energy Optimization Tool (https://messo.shinyapps.io/AEOP_/) was shared with the participants. This tool can be used to simulate an optimize system for the dairy sector. A sample optimization for a rooftop PV system for a dairy farm, based on the herd size, milking time, number of milking units, investment cost for solar PV, feed-in tariffs etc. was conducted. This generated a result with monetary analysis, electricity analysis and environmental analysis which was shared with the participants.

During the presentation, a poll was conducted among the participants asking their monthly electricity consumption. The results of the polling showed an average consumption of 300-400 kWh (29%) represents the average household electricity consumption in Ireland, which is approximately 350 kWh per month per household (Selectra, 2021).

Energy Efficiency in the Residential sector:

The objective of the presentation was to orient the participants on the topic of energy efficiency in the residential sector. The content of the presentation was:

- Introduction to the concept of energy efficiency and its importance
- Energy consumption by sector in Loop Head
- Introduction to BER ratings and steps for improvement
- Thermal performances of houses
- The heating requirement of existing buildings
- Factors not captured by BER rate

During the presentation, some of the key points which were discussed were how energy efficiency can improve the building energy requirement and enhance comfort levels. The participants were informed of the Building Energy Rating (BER) standards, and the requirements to achieve different BER rating. They were informed about possible improvement on building envelope, heating improvements, renewable technologies which could improve building energy efficiency performance thus leading to higher BER ratings. Participants were also informed about the retrofitting analysis, which talks about the effect of various improvement on BER ratings. Also, an example of how updating building fabric can improve building energy performance was illustrated. Lastly, the limitations of BER ratings were also explained, which are mostly related to human behavioural aspects of the occupants.

Key Takeaways

The objective of the sessions on the energy audit and energy efficiency in the residential sector was to capacitate them to relate these topics to their household. Information on their energy consumption and experiences with energy auditing was shared by participants. Household energy efficiency status, retrofitting measures undertaken in their households, and current BER ratings were also shared. The details on the key discussion are also mentioned below for further insight into the main discussions.

- It was observed that participants' knowledge is heterogeneous in the sense that some have been exposed to the energy sector and knowledge and many are less exposed, for example, two of the participants shared their experience with the installation of a solar rooftop PV system. The size of PV system was 4.76 kWp and 3.06 kWp. The information on the energy purchased, PV generation, and export to the grid was shared. Those participants were encouraged with the performance of the PV system and recommended it to others.
- Participants were also aware of the use of energy-efficient appliances, replacing conventional lighting with energy-efficient LED lights, use of appliances based on the energy efficiency ratings and also turning off appliances when not in use to reduce energy consumption.
- A poll was conducted after the presentation sessions, which collected the energy efficiency situation in the 20 participants households. The finding of the poll showed that the majority (75%) of the participants want to improve energy efficiency to reduce their energy bill followed by improving the comfort levels in their household (55%). Only 7 participants had done BER rating of their houses with 5 having A-B and 2 with C-D rating. The majority of participants have retrofitted or are willing to retrofit their Roof, which is followed by windows and doors and improvement in walls.
- A participant expressed that there is a strong will to generate energy locally in the Community as a community energy project.
- It was suggested that a future pathway for the Loop Head community could be to retrofit few households in partnership with SEAI. Which could encourage others who are lagging to follow and implement energy efficiency measures.

Session 2

Date: Wednesday, 24th February 2021

The session started with a recap on the topics discussed in the 1st workshop on 22nd February. The second workshop was also conducted in the presentation plenary discussion format. The presentation and discussion for the workshop were focused on the topic of Circular Economy, Anaerobic Digestion and Solar Photovoltaic technology. The first topic on Circular Economy and Anaerobic digestion were jointly presented by Aadit Malla and Mary Obando. The second topic was presented by Carlos Epia and Tatiana Carvalho. The Session was attended by 23 participants from the Loop Head Community.

Circular Economy, Anaerobic Digestion

The objective of the presentation on Circular Economy and Anaerobic Digestion was to introduce the participants to the underlying concept of Circular Economy, its principles and some technical background on Anaerobic Digestion. The main idea behind the presentation was to sensitize participants on the topic and create a dialogue on how it can be applied in Loop Head Community. The details on the content presented are listed below:

- Introduction to Circular Economy and its principles
- Importance of circular economy
- Best practices on Global Circular Economy
- Circular Economy in Dairy Farms
- Introduction to Anaerobic Digestion

The definition of Circular economy was presented to the participant. The difference between the Linear Economy (take-make-dispose) and Circular economy was elaborated. Principles of a circular economy; design out of waste, build resilience through diversity, energy from renewable resources, think in systems, and waste is the food of another process/product was discussed. A video on the circular economy: definition & Examples (https://www.youtube.com/watch?v=X6HDcubgxRk) was shared with the participants to better understanding the concept discussed. Some success stories on the implementation of the circular economy were shared, which includes an example on circular ocean project, VenloCity C2C

Design, Good Food Brussels presented at joint workshop "Pathways to a circular economy in cities and regions" (ESPON, 2016).

The dairy sector plays an important part in the economy of the Loop Head community. Understanding this importance, the concept of circulatory in Dairy Farms in Loop Head was covered in the presentation. The advantage such as improved resource security decreased import dependency, reduced environmental impact, economic benefits and social benefits which can be achieved with the application of circular economy in dairy farms was presented. This was done to introduce circularity to different processes and activities, feed to fertilizer, in the dairy sector. The concepts of extensive grazing, intensive-high tech and optimized grazing were elaborated. The presenter suggested the optimized grazing approach as a suitable scenario for the dairy sector as it has lower upfront costs and other improvements can be made gradually.

Biogas

The sources which can be used for biogas production was presented. The participants were presented with the working principle of the Anaerobic digester process, and various application of biogas. The idea of Anaerobic digester application in Farms was presented.

Key Takeaway

The objective of the sessions on the Circular economy was to introduce the concept and sensitize farmers to apply this to energy generation through biogas and at the same time produce fertilizer required for farms. During the presentation and discussions, participants were also informed about different wastes which could be used for biogas production. In the case of solar in individual farms participants were informed about different solar technologies. Input from the participants was collected to design an optimum size of a PV system, during the process participants were informed about the important parameters for designing a solar rooftop system.

- The participants were in general interested in using an anaerobic digestor at an individual level. They were curious about the use of circular economy at a farm level, type of biomass that could be used for biogas production. Some of the participants are already conducting some market research on farm level biogas plants. The biomass model being developed can be a useful tool for the participants to estimate the biogas yield based on the available biomass feed.

- As learned from the session on 22nd February, participants are interested in the solar PV system. This session briefly presented the different PV module technology and collected important feedback from the community on the PV model being designed.

Rooftop PV systems

The second presentation was on the topic of Rooftop PV systems. This presentation was intended to provide the participants with basic knowledge on the principle of solar energy, its functionality, costs and introduce participants to the IC 2021 Solar PV optimization model. The details on the content presented are listed below:

- Source of solar energy
- Components of rooftop PV systems
- Cost range of Solar PV
- Benefits of installing a rooftop solar system.
- Identifying Optimum size of a solar rooftop PV system.

The presentation started with the fundamental of solar energy. The basic working principle of the solar photovoltaic system was presented, and different types of solar panels were introduced. A schematic view of a basic rooftop solar PV system and the range of solar PV systems were shared. Different decision criteria for PV system optimization mentioned below were discussed:

- Cost of the PV system
- Future bill costs
- Internal rate of return (IRR)
- Total NPV of the investment,
- The carbon footprint of household electricity

The Level of Smart export guarantee per year in the high and low scenario of the planned Feed-In tariff policy was shared with participants. The model for optimization of PV system for farms and individual household in Loop Head which was under development was introduced. Participants were also asked about their expectation from the Model.

Session 3

Date: Monday, 1st March 2021

This was the third session and the first in the second week. The session was focused on community energy planning, drawing lessons from the experiences of communities in Scotland; Shetland and Applecross, hosts of International Class in 2019 and 2014, respectively.

John Aston discussed the current situation in Loop Head, indicating that there are immense energy resources, a strong energy demand and a lot of money is spent to import energy to the Loop. John also highlighted that the Loop Head is starting fresh and has a lot to be done and therefore, welcome all ideas and experiences. He went on further to introduce the participants from the community to the invited panellists.

Statement by Ms Alison Macleod on Community Energy in Applecross

Ms. Alison Macleod spoke about Applecross but first introduced herself, detailing her roles within the Applecross community company. She discussed the community's partnership with Community Energy Scotland, who provided financial and technical support to the community. Ms. Macleod spoke about the challenges with mobilizing interest, land ownership, and the initial plan for income generation as part of a government scheme to promote renewable energy generation and the lead up to the decision to use the energy locally, instead. Ms. Macleod also spoke extensively about financing and the challenges they faced with that before detailing how this was addressed by offering shares to community members which are to be bought back within 20years when the feed in tariffs would expire. She also discussed some of the plans for the community to develop energy-related projects such as development of energy efficient affordable housing in partnership with the housing association. There are also plans for electric vehicle charging system with a view to have a shared electric vehicle for the community. One of the plans is to develop community transport, currently a number of locals have electric bikes and there are electric trailers to deliver local food supplies. She concluded on the ongoing development of wood biomass (timber) to be exported from a community owned woodland area.

Presentation by Ms. Elizabeth Johnson MBE and Ross Gazey

Ms. Elizabeth Johnson and Mr. Ross Gazey made a presentation on Successful Community Project Examples looking at the sustainable energy journey of Shetland. Ms. Johnson introduced the Pure Energy Centre and the work of the organization, citing that the success of the Pure Energy Centre is an example of how a small community initiative can leap to become a global phenomenon. Ms. Johnson also explained the journey from working on electrolysis to taking control of all the components of the hydrogen production system and refilling station. The Pure Project is the first community renewable hydrogen project in the world which was first established for wind to heat. The community also got the first hydrogen system in a container, which was trademarked HyPod which led to some legal complications with Apple for sounding like iPod. The community would win the legal battle showing what a community can do. The success of the hydrogen project led to the establishment of the Pure Energy Centre. And through the Pure Project, the Pure Energy Centre was involved in tens of millions of pounds which has benefitted the Shetland community greatly. Mr. Ross Gazey also discussed the circular economic model in the Outer Hebrides which was subject of the IC2019. The project includes the use of an anaerobic digestor combined with wind to produce hydrogen. The hydrogen is used to power refuse trucks. There is also a fuel cell which powers the salmon hatchery. The salmon hatchery uses oxygen from the hydrogen electrolyser and waste from the hatchery is used in the anaerobic digestor, making the system a completely circular economy. The Yorkshire Forward project was also described. The project provided energy for the EETC building, a technology centre which serves as an innovation incubator. The project included a wind turbine which is used to power a 30kW Electrolyser, combined with storage and fuel cell to power the building. This is evidence that the application of renewable hydrogen can be in both urban and rural settings. The presentation concluded with an overview of the community benefits listed below:

- Promote H_2 and potential for further projects

- Create new business ventures in a community
- Inward migration
- Potential for new exciting jobs
- Support the local community by re-investing in it
- Green technology brings technology tourism
- Raise the profile of your area
- New ventures attract other businesses
- Do not be afraid to aim high
- Always ensure community benefits are high and any project contains budgets for local management
- Upskilling of workforce –stop the brain drain
- Energy/fuel security
- Income generation

Takeaways

To deduce some takeaways from the session based on the objective to familiarize the community on the planning process according to the experiences in Shetland and Applecross, a question was asked at the beginning of the session and the following were the responses elicited at the end.

Question: From the presentations and discussions about the community energy projects in Scotland, what could be applicable to Loop Head?

Responses:

- To work with what you have and from there, comes ideas.
- To choose a project that uses the resources we have
- Get an overview of the available resources and used that to decide which projects to start with
- Think BIG if you can!

- Check under every rock and trace every loose thread to find what has worked elsewhere and use that momentum to push through the education.

Session 4

Date: Wednesday, 3rd March 2021

The final session for IC 2021 in the LEAP Energy Academy workshop looked at the model developed – The Loop Head Energy Model. Details of the model are discussed in Chapter **Error! Reference source not found.**. The objective of the session was to familiarize the participants with the model, starting with presentations detailing the components, dashboard, input and output parameters of IC Model 2021, followed by a breakout session allowing the participants to work with the model to develop a scenario. The presentations were made by Aastha Bhattarai, Anish Chandra Pyakurel and Michael Adepoju, who headed the development of the model.

Aastha defined Energy Modelling before going into details of the Loop Head Energy Model. She discussed the objectives and the sections of the model. Anish illustrated the working of the Individual section of the model, i.e., the BER estimator and Solar Calculator, which are designed following the methodology explained in Chapter 4.1.4 and Chapter 5.2.2 respectively. The Solar calculator is used to determine an appropriate size of PV System for a household or farm while the BER estimator helps the user identify the retrofitting work needs to be done to improve the BER rating of the household and the potential associated costs. Michael on the other hand explained the community model by first describing the user interface. He informed the participants of the contents of the various worksheets, tabs, charts, and work cells. Michael also demonstrated the working of the model by developing a scenario with an objective of reducing annual net energy spending in the Loop by 2 million Euros.

Breakout Sessions

In the first breakout session, the discussion began with identifying the objective, which as mentioned in the Chapter 1 is to conserve energy and reduce spending on energy. A scenario was developed to this effect, focusing on generating energy locally with rooftop solar for households and farms, and community solar and wind farm. In addition, energy efficiency measures for up to

25% of households was considered in the scenario. The output of the simulation indicated that, an investment of over 5 million and 2 million Euros is required for the renewable systems and retrofitting, respectively. This will bring a saving of about 2 million to the Loop from the 6.9 million spent annually. The participants however noted that the retrofitting requirement for some of the households may not be achievable. To make this point, the BER estimator was used to estimate the cost of retrofitting for the house of one of the participants which was built pre-1919 and was a detached stone wall house. The model results showed that more than 30,000 Euros will be needed to retrofit the house. From the discussion, it was highlighted that this is the situation for many households in the Loop and as such emphasis should be put on installing PV systems for households to generate their own electricity and to develop community energy schemes to reduce the net spending on energy for the community as a whole.

The second breakout session was presented by Michael Adepoju, this session started with a reiteration of various components on the Input-Output tab of the energy model. During the session, multiple cases were tested based on participants request. In the beginning, a possible case of installing a 10 MW wind power plant was tested. With this capacity of a wind turbine installed, the model generated annual total electricity of 30,805 MWh. Out of this generation, 18,890MWh was exported to the grid. A possible scenario with heat pump in 20% of residential houses was tested, the output indicated that with the installation of heat pumps, 0.5 Million Euros can be saved from annual net spending on energy, which is 6.9 million Euros. Another scenario with 25% (312) of occupied houses installing 3 kWp solar rooftop system was simulated, the results were 901 MWh of electricity generation per annum and the investment requirement was estimated at 1.1 Million Euros. The model also showed that with SEAI grants this investment requirement could be reduced to 468 thousand Euros. A case of installing a 15 MW wind power plant was tested, the output showed that with a feed-in tariff of 6 Euro cents/kWh the annual revenue from electricity export would be 2.06 million euros. Participants were also guided to update the calculation parameters, to update the model to adjust future price changes and to adjust capacities of RE technologies. A case with a 20% increase in the number of farms with less than 100 Cows were simulated, which led to increase in electricity demand by around 200 MWh per annum. Lastly, a

20% increase in an electric car was simulated, which showed a possibility to reduce fuel cost by 500 thousand Euros.

Takeaways

- The community members present were keen on reducing their own energy consumption and carbon footprints. The main motivation being to reduce their spending on energy.
- In order to get more members of the community on-board, individual members of the community will need to be shown how much impact their individual efforts have on the overall energy balance of the community, the associated costs, and benefits.
- Retrofitting households is important to reduce energy consumption, however, given the associated costs, pursuing rooftop PV installations seems to be of highest priority to the community members present according to a poll conduction during the discussion. The result of the poll is found in the Appendix H.4124. It is worth noting however, that installing PV systems without improving the household energy efficiency may not reap the desired results.
- The model has great potential; despite the limitations, the community members present are keen on working with it. About two thirds of the community members present expressed a desire to master the use of the Loop Head Peninsula Energy Model with at least an in-depth understanding.
- The community members present expressed great satisfaction and appreciation to the students for the workshops. The feedback given was positive and indicated that the participants have understood the theories, concepts, technologies, and terminologies discussed during the course of the workshops.

8 Conclusion

Under the prevailing conditions set forth because of the COVID-19 pandemic, IC 2021 had to be conducted in an unprecedented manner. Without jeopardising the aim of international class, IC 2021 was designed to focus on objectives achievable within the context of the limitation of activities to virtual interactions, literature-based desk research, online workshops, and computer simulations. The objectives, nature, and scope of IC 2021 is certainly indicative of the situation, albeit the results generated are unalloyed by the circumstances.

Over the course of the sessions hosted by international class 2021 in the LEAP Energy Academy, the community has shown great interest in the energy topics discussed and have always contributed significantly to the discussions with educated questions and comments. The presentations were well received and the feedback from the community indicate that the explanations were clear and well understood. While the objective of the sessions was to familiarize the participants with some of the topics, concepts, and terminologies relevant to community energy, the participants have expressed a willingness to continue the discussions with other community members out of the sessions. This indicates that they are comfortable with the concepts and terminologies introduced during the workshops and the objectives for international class 2021 has being achieved to great extent.

IC 2021 has found that, to record savings in the heating demand for the residential sector, improvements in building envelope material and level of insulation is a necessity for households. Replacing oil boilers with more efficient clean heating technologies can further reduce household expenditures on fuel and reduce carbon footprint. While many might be dissuaded by the cost of implementing energy efficiency measures, taking up such endeavours like retrofitting and installing heat pumps (air to water) could yield immense economic benefit for the community. As noted in the first session of the workshop, this may start with developing local skills and raising awareness of the grants and incentives available. In one of the discussions, it was also pointed out that some trainings are available through the SEAI for free. However, there must be a market built in the community for such skills to motivate a few people to take up such trainings. Having local personnel to carry out these works will greatly reduce cost and encourage more up take.

In addition to retrofitting and other energy efficiency measures, the Loop Head community could push for a community energy scheme. The report of IC 2020 has detailed extensively the potential for wind and solar in the Loop Head peninsula. Scenarios developed during the breakout session in the final workshop showed the Loop can drastically reduce the annual net spending on energy by implementing a community energy scheme using solar and/or wind. The community members will be motivated in this regard by the examples of the communities in Shetland and Applecross, which were presented as part of the workshop.

For the farmers in the Loop Head, IC 2021 recommends adopting circular economic practices to curb dependence on fossil fuels, improve management of cattle manure and improve overall energy efficiency in the farms. Given the interest in rooftop PV within the community members present during the workshops and those interviewed during IC 2020, installing rooftop PV in farms was analysed. The results indicate that farmers will recover their investment in rooftop PV within 9 years on average. The analysis of rooftop PV potential in Loop Head also lead to the development of a solar calculator which can be used both for farms and residences. It is expected that the solar calculator in the model will be of benefit in estimating solar PV system sizes and associated costs and benefits for the community. Installing PV systems in households and farms might perhaps be the most enticing for the community members since it is relatively feasible, and the available grants make it economical. The prospect for feed-in tariffs also adds a financial incentive.

In addition to the solar calculator, the model also includes a BER estimator which can be used to estimate the cost of retrofitting a household based on the year of construction, building type and desired BER rating. The solar calculator and BER estimator form the individual section of the model. The community section on the other hand allows users to simulate a scenario which could include inter alia, a community-owned energy scheme with wind or solar, adoption of electric vehicles, installation of rooftop solar, and household retrofits. In the penultimate workshop, the model was introduced to the community members present, who expressed enthusiasm towards the model and intend to work with it both for their individual enterprises and for the community partnership.

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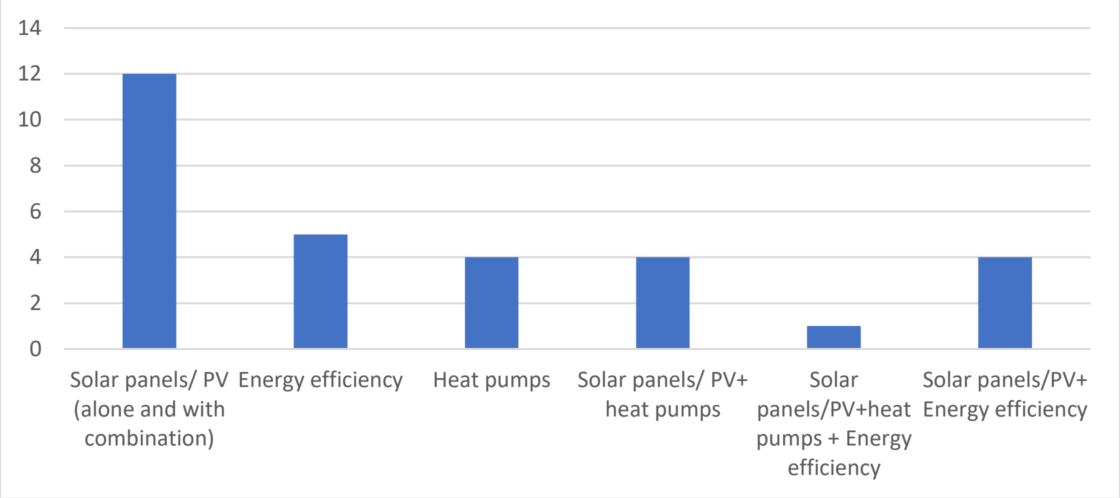
APPENDIX

A. Residential Demand

A.1. The results of poll conducted at the 1st Workshop to Community in 8th of February 2021.

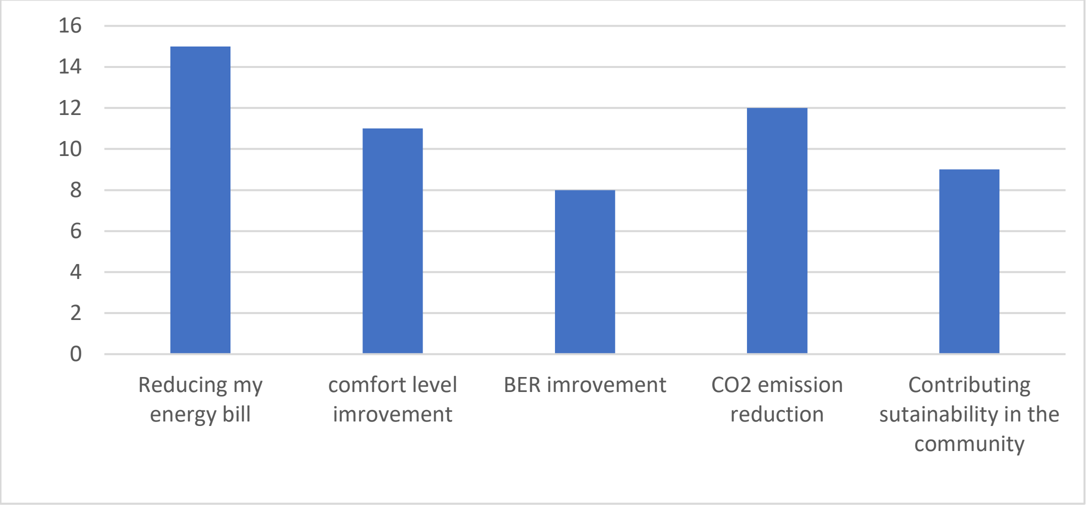
Question: What type of energy interventions are you considering?

The graph below summarized the number of respondents and the proposed options.



A.2. The results of poll conducted at the Workshop to Community in 22 February 2021.

Question: Why is improving energy efficiency is important for you?

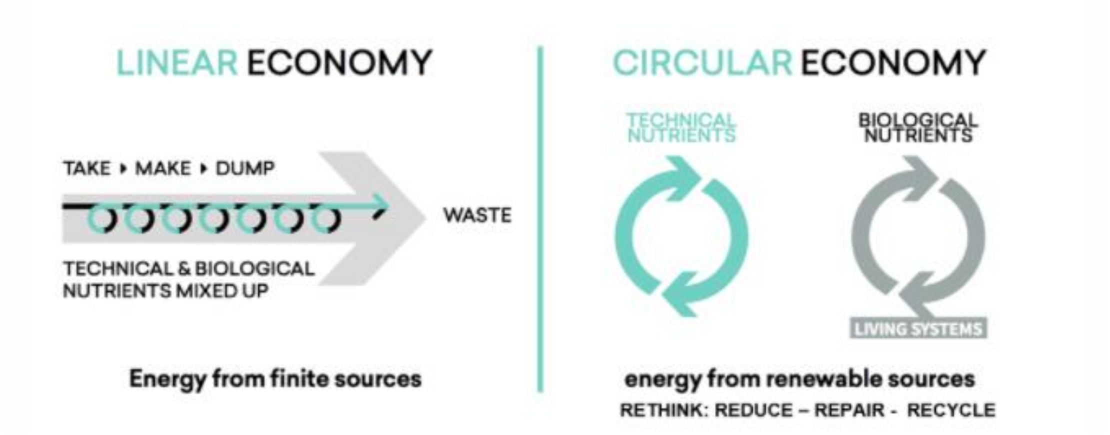

16
14
12
10
8
6
4
2
0
Reducing my energy bill
comfort level imrovement
BER imrovement
CO2 emission reduction
Contributing sutainability in the community

B. Theory on Circular Economy

A clear understanding of circular economy is important before diving into the implementation of the concept. This section describes the concepts and theory behind circular economy and its benefits to the local economy. Also, an in-depth technical background description on the proposed technologies for this study have been described in detail with an aim that the reader will be able to visualize the implementation of these technologies in farms in Loop Head to attain circularity.

The definition of circular economy considers three dimensions of: economic, environmental, and social aspects. “CE is a sustainable development initiative with the objective of reducing the societal production-consumption systems' linear material and energy throughput flows by applying material cycles, renewable and cascade-type energy flows to the linear system. CE promotes high value material cycles alongside more traditional recycling and develops systems approaches to the cooperation of producers, consumers, and other societal actors in sustainable development work” (Korhonen et al., 2018).

The “linear model” is a model that could be also called “take-make-dispose”. In this model the premise is simple: companies extract raw materials, use energy and create a product, and sell the product to an end consumer. This consumer is the one who discards the product when it no longer works or no longer serves the user’s purpose (Ellen MacArthur Foundation, 2013). The following figures shows a comparison between the two models, the linear model can be observed in the left side of the image where the flow is take-make-dump, and the energy is taken from finite resources. On the right side there is a representation of the circular model, which looks at reducing, repairing, and recycling while consuming renewable energy resources.



Source: (Sustainability Guide, 2018)

Figure: Linear and Circular Economy Models

Need for a switch to Circularity

A linear economy model incurs unnecessary resource losses in several ways, some of them are mentioned below (Ellen MacArthur Foundation, 2013):

- *Waste in the production chain:* between mining and final manufacturing significant volume of materials are commonly lost in the chain to produce different goods.
- *End-of-life wast*e: For most materials, the conventional recovery rates after the end of their first functional life is quite low compared with primary manufacturing rates.
- *Energy use:* In the linear model, when a product is disposed in a landfill this means that all its residual energy is lost.

Circular economy a model which refers to an industrial economy that is by intention; aims to use renewable energy, minimizes, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design.

According to the Ellen MacArthur Foundation, circular economy is based on a few simple principles (Ellen MacArthur Foundation, 2013):

- Design out of waste: waste is not present when the biological and technical components (or nutrients) of a product are designed by intention to fit within a biological or technical materials cycle, designed for disassembly and refurbishment. The biological nutrients can be simply composted since they are non-toxic.
- Build resilience through diversity
- Rely on energy from renewable
- Think in systems: In circular economy it is important to have the ability to understand how parts influence one another within a whole, and the relationship of the whole to the parts.
- Waste is food: waste produced in one step of the process should be considered as food for another step of the process.

A shift from linear economic model to a circular model significantly reduces negative environmental impact. The re-use and recycling of raw materials could show enormous potential in all global economic sector making efficient use of resources and avoiding waste. Bioeconomy is acknowledged as to be crucial for achieving circular economy by The Circular Economy Action Plan (European Bioeconomy, 2019).

The European Bioeconomy Alliance (EUBA) mention a coherent, supportive framework and policy as primary ingredient to ensure sustainable bio-economy and also emphasize on their ambitions to synergize the idea with circular economy (European Bioeconomy, 2019).

- Improved resource security: using better what is already used and using what is not yet used provide a form of resource security in terms of self-sufficiency. In the policy there is not mention a current resource insecurity but to have the availability of the resources would allow the community to be more independent,
- Decreased import dependency: With the escalation in the use of the locally available products, the dependency on the imports can be observed to reduce. In 2019 Ireland imported 87.7 billion of euros in different products (Observatory of Economic Complexity, 2021).

- Reduced environmental impact: A reduction of emissions due to less transportation requirements due to locally available resources and also less dependency on burning fossils fuels.
- Economic Benefits: As a result of new products from locally available resource and the markets for the same, economic benefits from these new markets can have significant impact on the local economy. Also, the reduced dependency on imported fossil fuels can result in substantial import savings.
- Social Benefits: A change in consumer consumption pattern along with creation of new job opportunities is expected to have significant positive impact on the society in the long run (ESPON and INTERACT, 2016).

As mentioned before, the following sections will cover technical background on the aspects considered in this study as a point of departure for the transition of the farming sector in Loop Head towards a circular economy.

C. Energy Audit

Energy audits are used to improve the efficiency of energy-consuming processes, to obtain an economic benefit because of a decrease in energy consumption. Nowadays, when climate change is a social concern and high cost of electricity an issue efficiecnt use of energy becomes important thus making “energy audit” absolutely necessary.

In 1980 the first edition of Handbook of Energy Audits (Thumann et al., 2013) which studied the term “energy audit” in detail was published and with its following editions has served as a reference to many energy auditors until the present day. The writers state that an energy audit can be simply defined as a process of determining the types and costs of energy use in the building, evaluating where a building or plant uses energy, and identifying opportunities to reduce consumption (Thumann et al., 2013).

There is a wide range of possibilities in terms of energy audits and it depends on the purpose for which it is done. Simplified energy audits can be performed economically to find energy savings in a house and detailed energy audits can be necessary for complex processes.

C.1. Levels of energy audit

Taking into consideration the scope of the project and level of effort necessary to meet expectations, (Thumann et al., 2013) describes four basic types or levels of energy audit.

- **Type 0:** This audit includes performing a detailed preliminary analysis of energy use and costs, and determining benchmark indices based on utility bills. This is very cost effective.
- **Type I:** It is called walk-though audit, and is a tour of the facility to visually inspect each of the energy using systems. It will typically include an evaluation of energy consumption data to analyze energy use quantities and patterns as well as provide comparisons to industry averages or benchmarks for similar facilities. It can yield a preliminary estimate of saving potential and provide a list of low-cost savings opportunities through improvements in operational and maintenance practices. It is the least costly audit and it is an opportunity to collect information for more detailed audit later on if the preliminary savings potential appears to warrant an expanded scope of auditing activity.
- **Type II:** It is the standard audit and it goes on to quantify energy uses and losses through a more detailed review and analysis of equipment, systems, and operational characteristics. This analysis may also include some on-site measurement and testing to quantify energy use and efficiency of various systems. Standard energy engineering calculations are used to analyze efficiency and cost savings based on improvements and changes to each system. It also includes economic analysis.
- **Type III:** Performed through use of computer simulation software to a more detail energy use by function and a more comprehensive evaluation of energy use patterns. The auditor will develop a computer simulation of building systems that will account for weather and other variables and predict year-round energy use. Because of the time involved in collecting detailed equipment information, operational data, and setting up an accurate computer model, this is the most expensive level of energy audit but may be warranted if the facility or systems are more complex in nature. (Thumann et al., 2013, pp. 1–2)

C.2. Process to conduct an energy audit

(Thumann et al., 2013) describes a long sequence of tasks to perform an energy audit. In case of farms some of them may not be relevant, and other new tasks may be required because of the farm process. The book divides the energy audit in three phases:

- **Pre-site tasks**
    - Collect and review one to two years of utility energy data. Tabulate and graph consumption and cost data. Check for seasonal patterns. Apportioning energy use among specific building systems such as heating, cooling, lighting and hot water. Pie charts of energy use and cost by fuel type can offer compelling documentation of overall energy uses and expenses.
    - Obtain mechanical, architectural, and electrical drawings and specifications for buildings.
    - Draw a floor plan of the building and calculate the gross square footage of conditioned space.
    - Calculate the energy use index (EUI), and compare it with EUIs of similar building types to have an indicator of the relative potential for energy savings.
    - Develop a list of potential energy conservation measures (ECMs) and operation and maintenance (O&M) procedures.
- **Site visit**
    - Prior to go to the site, sit down with the building manager to review energy consumption profiles and discuss aspects of the facility, as operation and maintenance practices, that may have an impact on energy consumption.
    - Fill out data sheets and look at the systems relating to the ECMs and O&Ms on your preliminary list.
    - Take pictures as you walk through the building and wrote down problems or additional opportunities.
    - Take basic measurements of light levels, temperature, relative humidity, and voltages.

- **Post-site work**
    - Review and clarify your notes
    - Review and revise your proposed ECM and O&M lists. Conduct preliminary research on potential conservation measures.
    - Organize information and write up audit report. (Thumann et al., 2013, pp. 9–14)

D. Biogas for waste management

Anaerobic digestion is a process through which bacteria breaks down organic matter into simpler organic compounds in the absence of oxygen (Environmental Protection Agency, 2021). Any organic source such as animal manure, wastewater, food wastes, agricultural residues can be used as input resource for the process. The principle of the short carbon cycle illustrates the primary benefit of biogas use over the use of fossil fuel sources. Unlike the later, biogas is generated from fresh organic materials. The CO2 captured by the biomass during its growth is released into the atmosphere during combustion of biogas thus just moderating the natural process over a short period, unlike the release of CO2 after millions of years, when fossil fuels are combusted. Animal farming result in large quantities of manure production which releases a significant amount of methane during storage. Stopping this methane emission is not a possibility. However, biogas provides a systematic method of capturing this high energy content gas and utilizing it as a replacement for other non-renewable energy sources (European Biogas Association, 2020).

Anaerobic digestion for biogas production takes place in a sealed vessel called a reactor/digester, which is designed and constructed in various shapes and sizes and vary widely on the technology in use, is site specific and is also widely affected by the composition and combination of feedstock in use. Biogas comprises of methane (CH4), which is the same compound in natural gas, and carbon dioxide (CO2). The methane content of untreated biogas may vary from 40% to 60%, with CO2 making up most of the remainder along with small amounts of water vapor and other gases (U.S Energy Information Administration, 2020).

When combination of multiple waste resources is used, the process is termed as co-digestion (Jia Lin, 2011). Co-digestion provides a degree of flexibility to the system and in terms of daily operation but also adds complication to the system adjustment of the system parameters. Hence the optimizing the share of the ratio of the of mixture becomes crucial.

The installation of an anaerobic digestor system on a micro scale can provide a diversification to the farm revenue and provide self-sufficiency for its energy needs. Also the recirculation of nutrients through the use of the digestate as the bio-fertilizer also promotes the contribution of the technology towards a circular economy (World Biogas Association, 2019). The process also contributes towards food security by reducing dependance on organic fertilizers and recirculating phosphorus into the soil. Also, sanitation and waste management are another benefit provided by the technology, sustainable management of which is a major objective of the study. In addition, the generated biogas also provides a possibility of storage which is not possible in other popular renewable energy sources. However due to financial and technical restrictions, biogas storage in large volume is not recommended on a small farm scale system and only to be done in small quantities to avoid wastage during maintenance (World Biogas Association, 2019).

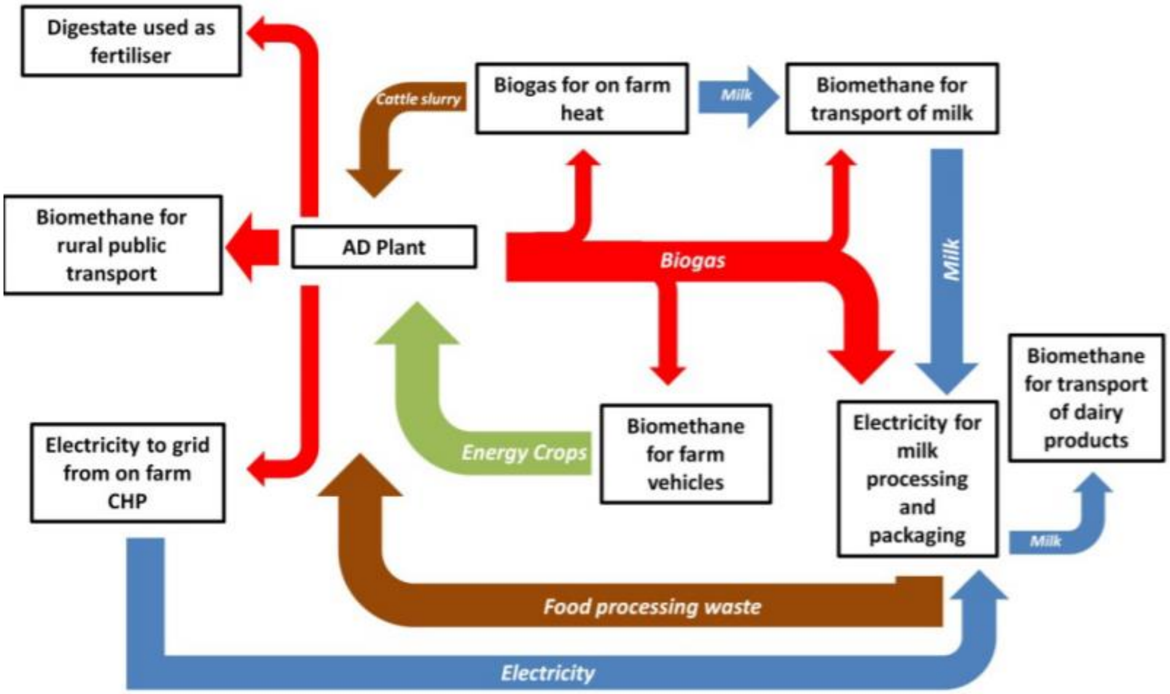
The social benefits are another aspect which makes the operation of the system in a rural setting even more attractive. In addition to the short-term construction employment, growth in newer enterprises contributing to growth in economic benefits can be observed. Also, improvement in crop yield and positive contribution to the agriculture sector can be anticipated.

The impact of biogas and biomethane towards reduction in emissions is noteworthy as it contributes to the reduction in fossil fuel dependence, prevents methane slips (Lukehurst and Bywater, 2015) from manure, stores carbon in soils, produces green fertilizers and enables carbon re-use. This gives a possibility to create a scenario of a negative carbon footprint (European Biogas Association, 2020).

The use of biogas and biomethane prevents the dependence on fossil fuels. Upgraded biogas provide the possibility for injection of natural gas grid, traditional gas application power generation and use in transport. Even though the grid injection may not be a possibility for Loop Head at present the later 3 provides immense opportunity to reduce the dependence on both micro and macro level on imported fossil fuel. In addition, the digestate, leaving the AD after the digestion provides a high grade biological and green fertilizer which substitute and replace the use of mineral fertilizers, avoiding the emissions related to their energy-intensive production (Lukehurst and Bywater, 2015). The upgraded gas also provides a possibility for application in the industrial process which could result in the establishment of potential market for the future (European Biogas Association, 2020).

Circular economy and Biogas

As mentioned in this introduction circular economy is an alternative to a linear economy. In a circular economy resources are kept in use for as long as possible, with the maximum value extracted from them while in use, and materials and resources are recovered and regenerated at the end of each service life. The application of the circular economy principal is well suited to rural farming communities. As proposed by Blades et al (2017), an anaerobic digestor and biogas production could be at the center of a smart sustainable energy infrastructure. The image below shows the example presented by Blades et al, farms will supply, and slurry feedstock and local industry will supply food waste to generate electricity and biomethane. As it is observed in following image the energy produced will go back into the local community, providing fuel for the farmyard vehicles, local and industrial transport. In this image can be observed that the electricity produced can supply electricity to farms, homes, and industry. The digestate which is a coproduct is utilized as fertilizer (Blades et al., 2017).



Source: (Blades et al., 2017)

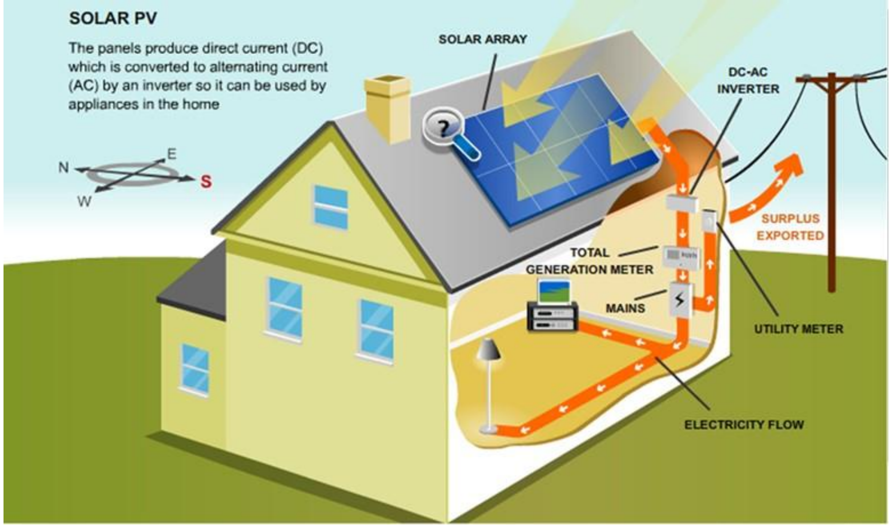
Figure: Biogas for Circularity in Dairy Farms

E. Solar PV systems

Solar photovoltaic power (PV) offers farmers the opportunity to achieve sustainable agriculture and the ability to reduce energy bills. As part of the government policy priorities, incentives to encourage the production of renewable energy has been designed. Further analysis into policies and regulations for solar PV system installation in Ireland can be find in chapter 3.

The most common solar energy systems designs are grid-connected, grid-connected with energy storage, off-grid. The grid-connected system is connected to the local electric grid, consuming energy from the grid in case the production cannot meet the demand and sending back to the grid in case the production exceed the consumption. The grid-connected with energy storage system is similar to the grid-connected design but presents an energy storage system usually in the form of battery backup. The off-grid system is not connected to the grid and is usually installed in remote areas where it not viable the connection to the electric grid. (Solarvest, 2021)

In this work, it is simulated a rooftop grid-connected system and the design is shown in the **Error! Reference source not found.**:



Source: (TendersOnTime, 2021)

Figure: Grid-Connected Rooftop Solar PV Systems

The Solar PV rooftop system is basically a small power plant at the rooftop, and it consists mainly of the solar PV modules, mounting structure for the modules, an inverter, and the metering. (TendersOnTime, 2021).

There are three main types of solar panels in the market: Monocrystalline - Mono-SI, Polycrystalline - Poly-SI and Thin-Film Solar Cells – TFSC. They differ in cost, efficiency rate, lifetime, flexibility on the modules to be installed and space efficiency. (Greenmatch, 2021).

F. Policies and Regulations

F.1. Circular Economy

In 2020 the government published the “Ireland’s National Waste Policy for 2020-2025”. This document states that the government is fully committed to transition to a circular economy. As a result the government of Ireland created the “Waste Action Plan for a Circular Economy” , the aim of this plan is that Ireland places at the vanguard of the European Union efforts to transition to a circular economy level (Government of Ireland, 2021b).

In the “Ireland’s National Waste Policy for 2020-2025” some of the principal objectives of this policy are mentioned above (Government of Ireland, 2021b):

- Shift the focus away from waste disposal and treatment to ensure that materials and products remain in productive use for longer thereby preventing waste.
- Ensure that measures support sustainable economic models (for example by supporting the use of recycled over virgin materials).
- Harness the reach and influence of all sectors including the voluntary sector, R&D, producers. manufacturers, regulatory bodies, civic society.
- Support clear and robust institutional arrangements for the waste sector, including through a strengthened role for local authorities.

Bioeconomy is an option to achieve a circular economy in rural and coastal areas, this model can assist these areas in meeting challenges such as regional development and employment growth by introducing new business models, driving energy sector security by boosting the supply of domestic clean energy resources and maintaining and enhancing natural capital and protecting the environment. The government of Ireland is aware on how bioeconomy could move Ireland beyond simply a target compliance and carbon mitigation, in his case bioeconomy is focused in the integration of sustainable economic development which transitions to a low carbon and circular economy (Government of Ireland, 2018).

In February 2018, the government of Ireland released the National Policy Statement on the Bioeconomy. In this document the government of Ireland identified key actions for the future success of the bioeconomy.

Some of the key findings stated in the "National Policy statement on the Bioeconomy "are mentioned below (Government of Ireland, 2018):

- Ensure that there is coherence between all sectoral strategies which impact on the bioeconomy in Ireland.
- Establish a network comprised of representatives of commercial entities operating within the bio-economy and relevant public bodies to inform the future development of the bioeconomy.
- Encourage the translation of research into real world applications through promoting collaboration between research institutions (academia) and industry.
- Examine how greater primary producer, public and consumer awareness of the bioeconomy and its products could be built up - through knowledge transfer, advisory, sustainable business models, public procurement, consumer awareness campaigns and product labelling initiatives etc.

The policies found related to circular economy show that there is an interest from the government of Ireland in developing circular economy initiatives in the country, but more in a general scope. In case of the farming sector, it seems that the efforts to initiate a transition to circular economy started with the "National Policy statement on the Bioeconomy "but the documents shows more a starting point that a clear route on how to reach circular economy on farms.

F.2. 5.1.2.2 Solar PV

Currently, there are no support schemes in terms of feed-in-tariff in Ireland. However, the arrival of the SEAI solar PV grant in 2018 for existing domestic homes built before 2011 July encouraged micro-generation in private homes and result in a proliferation of solar PV and renewable energy throughout the country. A total of 4,353 homes benefits from the solar PV grant, installing 15MW of micro-generation, at a cost of €10.7m, saving 4,381 tons of CO2 emissions annually. After a scheme review in 2020, the grants rates suffer some changes, including the requirement of minimum Building Energy Rating (BER) rating to benefit. The strategy is to ensure the main principle of the scheme is pursued, which is energy efficiency. (Government of Ireland, 2021a).

A public consultation proposing a new Micro-Generation Support Scheme (MSS) was prepared by the Department of the Environment, Climate and Communications, from the Government of Ireland. It is part of the scope of the MSS to identify challenges that needed to be addressed to provide a path to market for citizens and communities to generate their own renewable energy, receive a fair and efficient price when doing so. (Government of Ireland, 2021a)

In response to this public consultation, in February 2021, the Irish Solar Energy Association (ISEA) elaborated a document providing contributions to the new Micro-generation Support Scheme (MSS) in Ireland. ISEA main goal is to increase in the rollout of solar PV and they emphasize that the incentive and support scheme for rooftop solar PV needs to be revised in order to achieve the government target by 2030. (Irish Solar Association, 2021)

Throughout a revision from the Micro-generation Support Scheme (MSS), the ISEA and its members provide their suggestion, as follows: (Irish Solar Association, 2021)

- Simplify the pricing structure.
- Reduce planning requirements.
- No BER preconditions
- Inclusion of new builds
- No export connection requirement

Regarding pricing structure, the Irish Solar Association suggested to include a Clean Export Guarantee (CEG) where more of the value of the Clean Export Premium (CEP) is reallocated upfront. For the planning permission requirements, they pointed it should ease the planning permission requirements for reasonable sized rooftop installations. Concerning BER preconditions and inclusion of new buildings, they recommended expanding the scope, including all rated houses and make new buildings eligible for the MSS scheme to ensure they engage in the solar PV rollout.

For the export connection requirement, the association suggested to avoid the introduction of any connection requirement for any additional export connection. (Irish Solar Association, 2021).

No substantial changes was promoted until this reported was written, although good perspectives to come in terms of new policies for Ireland. So, the current policies and regulation regarding solar PV system in the country remain the same as described in the report from International Class 2020.

According to the Enerpower website, a renewable energy grant is accessible through the Targeted Agricultural Modernisation Schemes – TAMS system, with grants available for energy efficiencies and renewable energy technologies. The Renewable energy farm grant was announced in March 2019 and opened one month later. (Enerpower 2021) Under certain criterias, the Sustainable Energy Authority of Ireland (SEAI) provides grants up to €3,000 for home solar panels. The criterias are: the house must have been built before 2011, must achieve a building energy rating of C3 or better after installing the panels and must get the panels installed by an SEAI-registered contractor. The grant is based on the size of system and battery also increases the grant amount. (Energyd, 2021).

As expected, to start in the summer of 2021, with the start of export payments of electricity, it is very likely that the grant scheme will end soon. It is announced by the government that the export payment should start in July 2021 and smart meters will be used to measure the surplus electricity exported to the grid. The plan for the scheme is composed by two main parts: (Energyd, 2021).

- Smart Export Guarantee: The Smart Export Guarantee will be available to everybody, no matter when the solar panels have been installed. And the payment of electricity exported to the grid will be based on the market value provided by the electricity supplier, with no cap on the amount of electricity sold.
- Clean Export Premium Tariff: It will be a bonus payment on top of the smart export guarantee, valid for solar panel systems installed after June 2021. It will be funded via public service obligation (PSO) levy and payments are capped at 30% of the electricity generated, with a maximum system size of 50kW.

Concerning planning permission, it is required for installation of solar panels on agricultural structures, or within the curtilage of an agricultural holding, house, or any buildings. It is considered exemptions ground mounted solar and roof mounted under certain conditions. The array of the ground mounted system shall not exceed 25m2 and the height of the free-standing solar array shall not exceed 2m. For the roof mounted, it shall not exceed 50m2 or 50% of the total roof area and the solar panels shall be a minimum of 50cm from the edge of the wall or roof on which it is mounted. (Teagasc, 2018).

For grid connections to the electricity distribution network operator ESB, no prior permission is required for systems up to 16A per phase that is 3.68kW single phase and 11.04kW three phase. If the system will export energy to the grid and is over 26A/16A, a pre-approval is required. The commission of the system must be in compliance with EN50438. (Teagasc, 2018).

It worth mentioning that, when a farmer is purchasing a solar PV system designed to be used primarily or solely in his or her farming business, a flat rate farmer can claim back the VAT incurred on the acquisition of the system. (Teagasc, 2018).

Thus, the existing policies on solar PV provide favorable grounds for the initiation of solar PV rooftop systems. Also, future iterations of the policy are expected to get favorable, further confirming a bright future for solar technology.

G. Energy Modelling

"Energy models are simplified versions and mathematical representations of the real energy system" (Poudyal and Paatero, 2013, p. 192).

A real-world energy system may contain an enormously large number of variables, constants, functions, or situations which even cannot be represented mathematically. A model categorizes similar variables, simplifies them by aggregating, makes rational assumptions, puts limits by assigning constraints, and applies best-fit mathematical equations to depict the real-world system as precisely as possible.

According to (Poudyal and Paatero, 2013), a model helps to understand the problem and to investigate the solutions. Similarly, an energy model helps to:

a. *Allocate resources*. The resources, in general, are scarce and expensive. Resource allocation helps in the effective planning of required resources and assists to utilize resources optimally.
b. *Find optimal solutions*. There could be more than one solution to any problems. But within any solutions, there can be just one optimal point. Models use mathematical functions to calculate the optimal point where there are no other feasible solutions.
c. *Explore and predict the future*. The statistical functions applied in the model analyze previous trends and anticipate the future over a period.
d. *Visualize complex systems in a comprehensible format.* With the help of information categorization, visualization techniques, and systemic design, a model can help to understand and visualize the complex system.
e. *Organize the data.* Models allow to enter the data in the desired datatype, and tabulated format which helps in the data query.
f. *Provide a consistent framework for testing any hypothesis.* It could be impractical or expensive to perform tests in the real energy system. Hence, a model is convenient to test the hypothesis repeatedly.

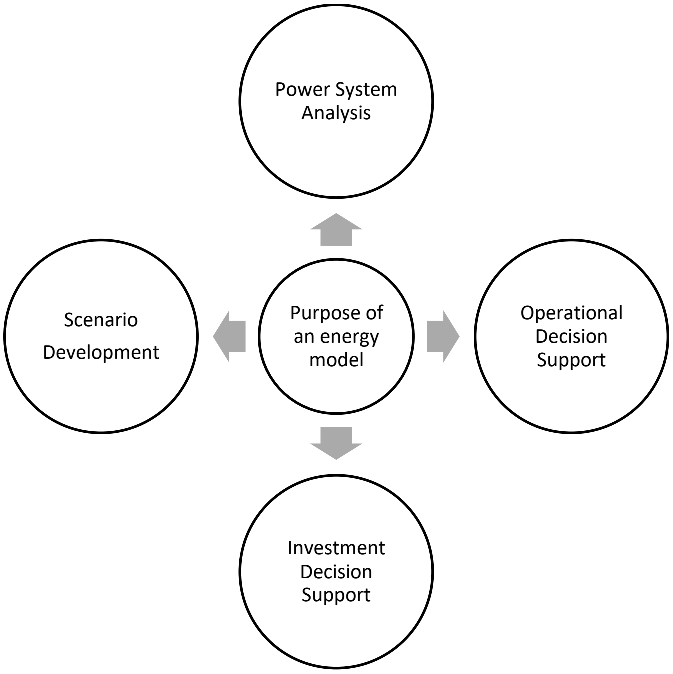
g. *Communicate assumptions among decision-makers and between decision-makers and stakeholders.* It helps to make decisions transparently by communicating assumptions and believes between the decision-makers and other stakeholders.

An energy model can be developed using programming or using any specialized software.

G.1. Purpose of Energy Modelling

As a model is always the simplification of a real system, it lacks certain details. It depends upon the objective and purpose of the study to identify what level of detail to include and what not to include. The more purposes we want a model to serve, the more complex it becomes. Hence, there is always a tradeoff between objectives and the simplicity of a model.

(Ringkjob et al., 2018) have identified four purposes of energy models. A model can be developed to serve just one of the following purposes or to serve several or all the purposes.



Source: (Ringkjob et al., 2018)

Figure: Purpose of an Energy Model

a. *Power System Analysis* – In order to study the electrical power systems for power flows analysis, grid stability analysis, fault level studies, etc. in detail, such models or tools are developed.
b. *Operational Decision Support* – To optimize the dispatch of the energy or electrical system, such models are developed. Such models work as a decision support system tool which studies the flexibility in renewable energy-based power system for stable operation of the system.
c. *Investment Decision Support* – An energy model could have the purpose of optimizing the investment in the energy system. The energy sectors have long investment cycles; hence, such models are usually long-term analysis models.
d. *Scenario Development* – One purpose of an energy model is to develop scenarios to evaluate the impacts of various policies.

G.2. Approach to Energy Modelling

(Nakata, 2004) has conferred about two approaches for examining the linkages between the economy and the energy system while developing energy models, namely; top-down models and bottom-up models.

Top-down model – Such models examine a broad equilibrium framework. The framework addresses the feedback between the energy sector and other economic sectors, and between the macroeconomic impacts of policies on national, regional, or global scale. Such, top-down model has limited detail in the energy demand side of the economy. In addition, the details on specific technologies are not directly captured.

Bottom-up model – The bottom-up models capture technological details from the engineering standpoint. For instance, a technique related to energy consumption, or supply, with a given technical performance and cost. The bottom-up energy models focus on the microeconomic level and detailed analysis of the technical and economic dimensions of policy.

H. Community Engament Workshops-Discussions

H.1. Session 1

Discussion I

The first discussion of the day took place after the presentation. The discussion session aimed to address questions from the participants on the presentation content. Also, to have interaction on energy consumption in the residential and farming sector, mainly the consumption pattern and the energy consumption by different appliances. Further to explain the concept of energy auditing to the participants.

Important questions:

Question: What is the impact of COVID on the energy consumption pattern?

Answer: The energy consumption for the residential sector during the COVID period might have increased due to increased household occupancy. But a detailed study is required to validate if there has been any change. A preliminary examination can be done by comparing electricity billings with the pre-pandemic year's bills for the same period.

Question: On the electricity bill the electricity cost is 0.1548 per kWh. How is the total cost calculated?

Answer: The total billing amount for the electricity tariff can be calculated by multiplying the tariff rate 0.1548/kWh with a factor of 1.135 to calculate the billing amount. The tariff as mention in the energy bills is net tariff rates which are exclusive of VAT of 13.5%.

Question: Is the energy bill inclusive of heating costs?

Answer: The average of 350 kWh/month is only for electricity and does not include the cost of heating.

Two participants shared their experience and the reduction in energy purchase with the installation of a solar photovoltaic system. The participants have installed a Solar rooftop PV system with a capacity of 4.76 kWp and 3.06 kWp at €10500 (€3000 grant) and €7730(€2730 grant), respectively.

Discussion II

Similar to the first discussion session, a discussion was held to clarify queries on the presentation content. Important questions that were asked by the participants are shown below:

Question: Do people have a feeling that the incentive available is not enough for people to make changes to their building?

Answer: An incentive is an economic mechanism designed to have something started. It is difficult to develop an incentive, particularly with technology like PV, which is developing at a rapid pace. The nature of incentive is based on the gradual removal of subsidies adjusted to the learning curve of technologies. In the case of building insulation, the incentives are poorly designed, due to the complexity of these activities.

Question: It is expensive to implement energy efficiency measures at Loop Head. How can this be resolved?

Answer: One of the ways to reduce the cost of energy efficiency improvement is to develop local skills. Additionally, this will create job opportunities and reduce the cost of rolling out energy-efficient technologies as more households will be interested in using the local manpower.

Question: What is the best way to insulate Stonewalled house?

Answer: The main problem with stone-walled houses is moisture build-up when insulation is applied to the inner walls. Insulation from the outside is the best option to insulate the walls to avoid excess moisture. However, the type of insulation is dependent on the actual wall structure.

Question: What are the steps involved in retrofitting a residential building?

Answer: In the first step a BER assessor will examine the house for insulation level for walls, roof, and windows, installed heating system, and the total energy demand is calculated. This collected data is entered into the SEAI tool (DIPAIR) to examine the BER rating. After the implementation of recommendation based on BER assessment, an energy audit is conducted to check the energy efficiency performance. In the case of installation of a heat pump as per the criteria, a house must reach a certain level of energy performance to maintain the coefficient of performance of the heat pump. Also, a preliminary online assessment can be conducted with SEAI online tools that provide recommendations to improve building insulation to improve the building efficiency before getting an actual BER rating.

H.2. Session 2

Discussion I

A discussion session was conducted to clarify the topic discussed. Some of the important questions from the participants are:

Question: Is the idea of a circular economy only for a large scale or can it be scaled down for a farm?

Answer: It can be applied to small farms. But this could lead to higher cost. The best scenario will be to use a combined digester where the waste from farms in proximity can be used. Connecting the farms in proximity to a pipeline could be a potential way to reduce transportation cost. Farm size biogas technologies plant is a mature technology that has been in the market for more than 30 years. The main problem with the small biogas plant is the cost of the auxiliary system which is proportionally higher for smaller biogas systems compared with larger systems.

Question: Slurry is an important part of the Farming sector, how is using an anaerobic digester advantageous to farms?

Answer: Anaerobic Digester can be used both as a waste management solution and a way to generate Biogas. Additionally, a co-product from the anaerobic digestion can be used as fertilizer. This fertilizer is mineralized and has higher nutrient content and can easily be absorbed by the plants.

Question: Would it be beneficial to add excess seaweed from beaches to the anaerobic process?

Answer: As long as a consistent supply is available, it can be used for biogas production. The IC 2020 conducted a study of using seaweed, but the initial study showed that the biggest obstacle in this approach was the logistic cost, collection cost, and the amount of seaweed available. Seaweed directly out of the sea cannot be used in anaerobic digestion due to the salt presence and requires a cleanup before being fed to the digestor.

Question: What is the breakeven size for the Biogas plant?

Answer: A recent study from Ireland, "Economic and Environmental Analysis of Small-Scale Anaerobic Digestion Plants on Irish Dairy Farms" (https://www.mdpi.com/1996-1073/13/3/637/htm) shows that Biogas plant with a herd size larger than 100 will have a payback time of 7 to 13 years.

Question: What type of residue can be used? Do general garden waste and food waste / certified compostable packaging waste would be suitable and useable in the AD plant?

Answer: Biomass Waste which is rich in fat and starch can be used for anaerobic digestion. It is important to maintain a balanced source of Biomass as the size of the biogas plant depends on the type of feed source. Concerning packaging waste, it can be used for the AD process if the packaging is starch-based and is made with biodegradable materials.

Question: What size AD system would deliver the necessary outputs to operate the Waterworld?

Answer: The AD system can be estimated using the current energy requirement. Based on IC 2020 study, there are two 500 kW oil boilers and the energy consumption for three months of operation was 147.8 MWh. It was estimated in the same study that a biofuel plant with a capacity of 150 kW will provide sufficient energy required to power and heat water.

Discussion II

A discussion session followed the presentation session to clarify the questions raised during the presentation. Some of the important questions are listed below:

Question: Do the panels degrade with age?

Answer: The design lifetime of a solar panel is about 20 years on average. Annually panels degrade at a linear rate of 1% to 1.5% of their rated capacity. This degradation is high during the initial age of the panel. The degradation of panels also depends on the ambient temperature and due to the cooler temperature in Ireland, the degradation of the panel is expected to be slower than in a location with a hot climate.

Question: Is there a difference in the maintenance requirement for different PV panel technology?

Answer: There is no specific maintenance requirement for different panel technologies types, the common maintenance requirement is to keep the surface clean.

H.3. Session 3

Discussion I

Question 1: How did you galvanize the community to build interest and take ownership of the project?

Answer: There were people who were never going to be interested but a majority of people had thought about it. There was a high level of awareness about energy issues, the school children were a good audience. The students were very engaged and understood what was going on from the start. They also raised money to buy shares in the project and discussed how they could make the school building more energy efficient. The presence of the International class was also valuable, they visited almost every house and spoke to the people about energy issues. The community members were more enthusiastic to listen to them.

Question 2: Did you receive LEADER Funding? Was there any local authority or local government funding?

Answer: There was LEADER funding for the community toilet for solar panels to provide warm water. There was also Scottish Rural Development Program funding through the EU.

Question 3: Is the land all community owned?

Answer: The land was owned by the Applecross Trust which is a charitable trust by the landowners and does not include any local community members. The community is renting the land from them. Because of the land reform by the Scottish government, they have started to sell land. The plan is to buy the land from them because otherwise they will end up owning the scheme as well, which is not acceptable.

Question 4: Who did the business plan? Did you have expertise in that area within the group?

Answer: We had expert advice from an accountancy firm that specialize in that area, who put the figures together. We also got financing to pay another community-based group who also completed a Hydro scheme a year before, to develop a business plan around those figures and I [Alison] turned it around to the local story.

Question 5: How has the Applecross Community Cooperative helped the households improve energy efficiency in their buildings?

Answer: Unfortunately, that was not a very successful scheme. There were lots of funding for energy efficiency but retrofitting households in Applecross is very difficult because the houses are very small and are mostly exposed to high winds. By the time the applications were completed there were not any grants, but loans and it was difficult to convince people to take up loans to retrofit their homes. There was training for local workers to carry out the retrofits and they helped some households. Community owned buildings were retrofitted instead because there was funding for that.

Discussion II

Question 1: How did the community organization start in the first place?

Answer: Like any sustainable community, there has to be someone to persuade the community. One of our community leaders thought Hydrogen was worth looking at. Some wacky things might have to be done to get the attention of people. In Shetland, school kids were involved in the naming the wind turbines, the prime minister was also invited to launch the project. This grabbed the attention of the community members and encouraged them to take ownership and now the community is proud of the achievement of the Pure Project and the Pure Energy Centre.

Question 2: Has the government helped? Is the limited involvement of the government a license to just get up and go? How could they have helped?

Answer: The government has not helped much but that has made us more determined to stand on our own and not depend on any government for money. There was a lot of funding for demonstration projects, but this was all put in one area. This could have been moved around a bit to allow communities to get their projects moving a bit quicker.

Question 3: How many local jobs has the community organization created?

Answer: The community organization has been working for a long time and has employed a lot of people. They also take on students in the summer to conduct projects and provided funding to community groups from the resources they have every year.

Question 4: It is better to not be reliant on any government as policy changes rapidly. The best thing for a community is to have its own income. How does this relate to the situation in Ireland?

Answer: Because of regulatory framework in Ireland, it is best to work in conjunction with the local authority but with a view of the objective of the community. If the community has their own income, they have a lot more freedom, but it is great if there is a working relationship between the community and the authorities because the community will still need to work within the regulatory framework.

Question 5: hat is the involvement of the county council in the development of the SEC master plan in Kilkee? Are there any communities where the SEAI are working with county councils?

Answer: At the moment there isn’t any involvement from the county council. The community applied for grant through the SEAI as a part of the community energy project. There is a mentor who comes and meets with the community to discuss what needs to be done and the objectives of the community. Then the application is filled, the company registered, and the community project identified. This is used to apply for grant aid. SEAI sent a list of energy auditors to work on the master plan. In Kilkee, the Tipperary Energy Board was selected, and the funding is now available to carry out the master plan. There are communities where the county councils play a role but that is primarily to provide bridging finance. In many communities where there are buildings, housing stocks, civic buildings owned by the local authorities, they become stakeholders.

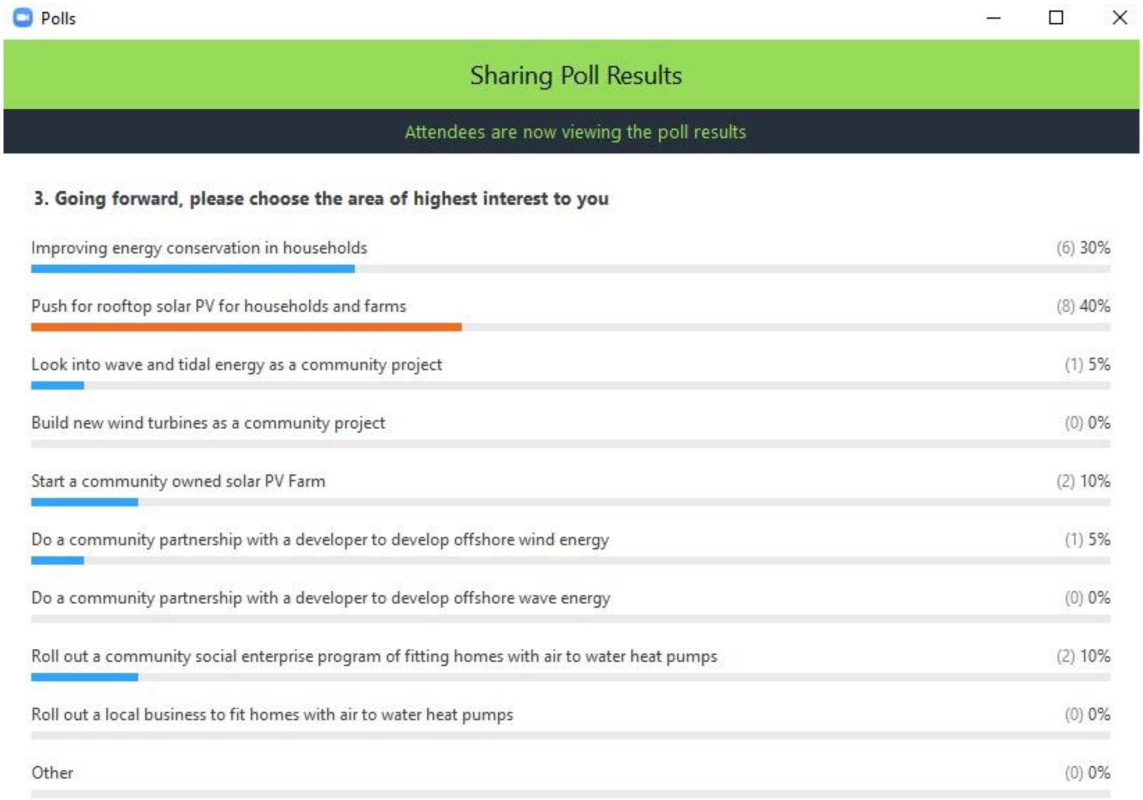
Question 6: Is their funding available to train people?

Answer: There are and will be opportunities for further training. There are also training courses in SEAI which are free.

H.4. Session 4

Discussion

As a prologue to the discussion, there was a poll looking at the areas of interest for the community members present going forward. The results of the poll indicate a high desire for retrofitting households to improve energy efficiency and installation of rooftop PV systems to generate energy locally. This was found to align with the objectives discussed in the first breakout session. The results of the poll asking the participants for their area of highest interest is as shown:



3. Going forward, please choose the area of highest interest to you

Improving energy conservation in households	(6) 30%
Push for rooftop solar PV for households and farms	(8) 40%
Look into wave and tidal energy as a community project	(1) 5%
Build new wind turbines as a community project	(0) 0%
Start a community owned solar PV Farm	(2) 10%
Do a community partnership with a developer to develop offshore wind energy	(1) 5%
Do a community partnership with a developer to develop offshore wave energy	(0) 0%
Roll out a community social enterprise program of fitting homes with air to water heat pumps	(2) 10%
Roll out a local business to fit homes with air to water heat pumps	(0) 0%
Other	(0) 0%

Question 1: What is the challenge with implementing total retrofits in household?

Answer: With the different types of house, of which only a small percentage are terraced and located in the villages in Carrigaholt and Cross, most of the other houses are standalone. Most of the people living the older houses are living alone and as such investing 30,000 Euro for retrofitting is a nonstarter. However smaller roof insulations may be more achievable.

Question 2: What percentage of the households can be fully retrofitted?

Answer: The data is not available but there could be a survey to count the single houses, older houses that need retrofitting. In the case of holiday homes, the investment required may be questionable based on the amount of time spent in it. However, if a holiday home is insulated, it may allow the owners to use it more often than usual.

Question 3: Should the model focus only on occupied residence houses since the holiday homes are occupied for only short periods of time?

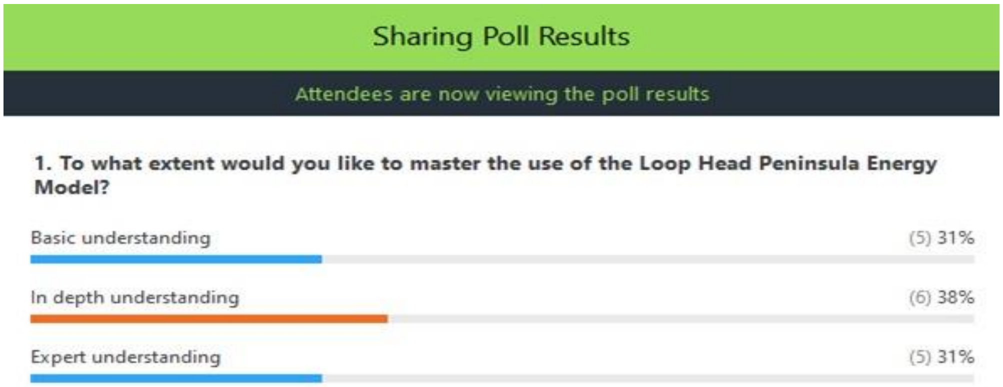
Answer: In the model, the heat demand values for occupied houses and holiday homes are 1300kWh per annum and 273kWh per annum, respectively. The limited use of holiday homes is already accounted for in the model. The values considered are from census data and can be adjusted when new data is available.

Question 4: Does the model also consider energy usage during non-use periods, such as energy used for heating to keep the house warm while occupants are away?

Answer: A lot people having heating system commands which allows them to control the heating for an hour or two a day, these systems are cheap and minimal. In the model the energy demand is aggregated hourly data and the profile of the heat demand is representative to some extent. This a challenge with all models that work on aggregated data and the model must therefore be simplified to meet specific objectives.

Question 5: To what extent would you like to master the use of the Loop Head Peninsula Energy Model?

Answer: The community members express interest in mastering the Loop Head Peninsula Energy Model, with two thirds of the participants expressing an interest to get at least an in-depth understanding on the model. This is shown in the poll results below:



Sharing Poll Results

Attendees are now viewing the poll results

1. To what extent would you like to master the use of the Loop Head Peninsula Energy Model?

Basic understanding	(5) 31%
In depth understanding	(6) 38%
Expert understanding	(5) 31%