A LEAP TOWARDS ENERGY SUSTAINABILITY FOR LOOP HEAD COMMUNITIES

FINAL REPORT

INTERNATIONAL CLASS 2020

Europa-Universität Flensburg

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List of Abbreviations

AD	Anaerobic digestion
B&B	Bed and Breakfast
BER	Building Energy Rating
BEV	Battery Electric Vehicles
CAPEX	Capital Expenditure
CH4	Methane
CHP	Combined heat and power
DH	District heating
DM	Dry Matter
E.g.	Exempli Gratia (For example)
ESB	Electricity Supply Board
EU	European Commission
EV	Electric Vehicle
FIT	Feed-In Tariff
GHG	Green House Gases
GWh	Giga Watt hours
GWhele	Giga Watt hour electricity
GWhth	Giga Watt hour thermic
HDD	Heating degree days
kW	Kilowatt
kWh	Kilowatt-hour
kWp	Kilowatt peak
LCOE	Levelized cost of Energy
LCOH	Levelized cost of heat
LHV	Lower Heating Value
LIT	Limerick Institute of Technology
LPG	Liquefied Petroleum Gas
Mio.	Million
MWh	Megawatt-hour
NTA	National Transport Authority
O&M	Operational and Maintenance
PHEV	Plugin Hybrid Electric Vehicle
PV	Photovoltaic
RE	Renewable Energy
REFIT	Renewable Energy Feed-in Tariff

RESS	Renewable Electricity Support Scheme
SEAI	Sustainable Energy Authority of Ireland
SEC	Sustainable Energy Community
SMEs	Small and Medium Enterprises
TAMS	Targeted Agricultural Modernisation Schemes
TEUR	Thousands of Euros
VAT	Value Added Tax
VRT	Vehicle Registration Tax
VS	Volatile solid
WDC	Western development commission

FOREWARD

Ireland is currently 86% reliant on fossil fuel (ISEA, 2019), giving rise to the agenda on radically reducing this dependence and making the transition to cleaner and more sustainable Energy systems. The Government of Ireland committed to meet the national targets through 40% renewable electricity, 12% renewable heat and 10% renewable transport to meet EU targets (Department of Communications, 2020). However, from these targets 6.8% was achieved for renewable heat thus far with other targets still to be achieved (Department of Communications, 2020).

An active participation from all of the stakeholders is needed to get the work done. With the mindset of community inclusion, Loop head Community has great potential in bridging the targeted gap. Stimulating conversations that pave way for communities to think about their energy balance and how they can become a Sustainable Energy Community, is paramount in reaching the set targets. The road towards a transition is one that requires full engagement with the community at all levels and to reach all peripherals.

A diverse team of Engineers from the University of Flensburg carried out different pre-feasibility studies to ascertain a possible starting point towards a sustainable energy community. Different sectors where under scope of research namely; residential, businesses (Hotels and B&Bs), Transport, Agriculture and Agro- Energy as well as Community Energy.

As Candidates of the Master of Engineering in Energy and Environmental Management we are motivated and inspired to be part of the building process of Loop Head Energy Action Partnership. Driven by the community's aspiration to become self-sufficient through the implementation of renewable heat technologies, energy efficiency and Energy from renewable sources.

We believe that this bottom up initiative will have a great impact within the community and for the government as a policy maker. As a team, this has been a great opportunity to implement and enhance our knowledge and competencies. Moreover, it has enabled us to fulfil our passion for community development. We hope this report will be a stepping-stone in challenging the status quo and moving towards a sustainable community documenting the process of learning, planning and doing.

Executive Summary

The population of 2567 people living in Loop Head peninsula pays 8.2 Million Euros annually on account of energy that is imported from outside to the peninsula. This study is conducted to help empower the community to examine the renewable energy potential with a view to support local sustainable development. Special focus has been kept on local issues of migration, lack of job opportunities and tourism.

The current situation is analysed to get to know the total energy demand. The total heat energy demand is 26 GWh, the electricity demand is 18.4 GWh and the diesel demand is 30 GWh. This data is based on several sources including the heat atlas by SEAI, the Irish census and own surveys and interviews conducted with the local community. The community played a vital role in the overall study by sharing their problems, ideas and possible solutions according to their experience in two workshops conducted in the beginning.

Most of the land in Loop Head is farmland. Only grass is grown which is used to feed cattle in the form of silage. There are more than 17,000 cows which produces slurry. The practical potential of slurry is around 66,249 tonnes per year. With present production techniques, an equivalent of 4,679 tons of silage per year can be produced on agricultural land which is currently not used. 21% of the total biomass resource can be used to produce energy. Additionally, the potential of wind energy is good with mean wind speeds of 9.2 m/s at a height of 100m above ground level. The solar daily specific yield ranges between 2.62kWh/kWp and 2.65kWh/kWp. This range is higher than the average value of PV in Ireland which is 2.51 kWh/kWp. Ireland lies in one of the best locations for wave energy as well. Installing a 1 km string Pelamis energy converter 30 - 40 km away from the coastline of the Loop Head Peninsula, would generate approximately 34 GWh/year of electricity These all sources have a combined technical potential to meet the energy demand of Loop Head.

Different sectorial demand shows that major part of heat and electricity consumption is in buildings meant for residence, holidays and B&Bs. There are a lot of vacant and holiday houses which usually have a demand only in the touristic season during summers. Other residential houses have greater share of those which are built before 1990. These houses are not properly insulated and hence have higher heat demand throughout the year. The major fuels being used for heating are oil, peat and coal. Improving the building insulation will reduce the energy demand and hence the use of imported fuels. Once the house is properly insulated, the remaining heat and electricity demand can be met with alternatives like solar roof top PV and heat pumps. 43% of the total heat losses takes place through roof and walls. The heat demand in Loop Head can be reduced by 30% with a total investment of 2 Mio. € and 60% by investment of 8.7 Mio. € . The second step is to change the heating system. Air to water heat pumps for average residential homes will cost around 10,000 Euros after grants from SEAI and in many cases they have an attractive payback time depending on the current fuel consumption. In buildings that are not suitable for heat pump, wood pellet boilers can be an attractive alternative. In an average residence a small solar PV systems of around 3 kW can save up to about 25% of the electricity demand and up to 50% of the fuels used for water heating. There are grants available from Sustainable Energy Authority of Ireland (SEAI) for building insulations, and other renewable energy measure.

The farming sector in Loop Head produces beef and milk. Apart from milk and meat, cows also produce slurry, which is currently used as a fertilizer on farmland. The farmers are interested in reducing the environmental impact of using unprocessed slurry as fertilizer and to add value to the slurry. The slurry and silage can be used in anaerobic digestors to produce biogas. This biogas can be used in boilers or CHP plants to generate power and/or heat; or can be upgraded to bio-methane and the used as a transport fuel or fed into the natural gas network. The total biogas that could be produced by slurry and silage in Loop Head would have an energy content of 7614 MWh/year, a quantity that could theoretically heat 475 houses. The study comes to the conclusion that under the present energy policies a biogas fed boiler that provides 1,250 MWh/year of heating for a district heating network of length 1580 m would be the most attractive solution, but still requires a conservable amount of public grants. The location of this biogas plant is proposed near Kilkee based on economic and technical constraints. This network can connect anchor loads of hotels and the swimming pool in Kilkee.

On the other hand, farmers can install solar PV systems on their roof tops to generate electricity to meet their electricity and water heating demand. Details are presented in section 9.

The transition in the energy sector must be driven by the community, so, options for community owned energy projects are also analysed in the report. There are grants available through SEAI for community energy projects. Pre-feasibility studies for community owned wind, solar and biogas plants has been conducted. As there is no feed-in tariff yet, a minimum tariff is assumed at which these projects can be attractive to develop. The minimum required tariff for solar in 0.21 Euro/kWh while that for wind is 0.068 Euro/kWh with annual energy estimation of 5.02 GWh and 6.6 GWh respectively. This assumes that the specific investment costs are similar to those in the UK. The capacity simulated of solar PV is 5MW and for wind is 2.3 MW.

The option of having public transport run on electricity is analysed against diesel. To serve 6, 000 passengers per year, about 5.5 Euros should be charged with a diesel bus to outweigh the costs, while for the electric bus charged using residential electricity tariff, the fare should be around 4.5 Euros and 4.25 Euros for the electric bus. The electric bus could be a profitable option to provide public transport as long as a cost-effective tariff for electricity for the vehicle is available.

A model is developed to analyse different scenarios and possible options. This can be used to see effect of each intervention individually as well as collectively with different renewable energy and energy efficiency measures in residential, commercial, services and transport sector. By tuning different parameters in model, the share of renewable energies can be reached to 100% and even more if total generation exceeds the total demand on annual basis

1 Introduction

The Loop Head peninsula is a headland on the south west of county Clare situated between the Atlantic ocean on one side and the Shannon estuary on the other side on the Wild Atlantics Way of the western coast in Ireland (Loophead.ie, 2020) .The Central Statistics Office divides Loop head into 9 Small Areas with a total population of 2,567 people and a total number of 2,982 houses (Central Statistics Office, 2016).

One of the main economic activities in Loop Head is tourism owing to the rich natural and historic wonders making it an attractive destination for tourists. According to (Loophead.ie, 2020) "Loop Head became a European Destination of Excellence in aquatic tourism". The Clare County Council, which manages the historic lighthouse in conjunction with the Commissioner of Irish Lights (CIL), reveals that the visitor numbers in 2018 was almost 25,000 visitors (Clare county council, 2019).Farming is one of the main economic activities in this area, most of the local farm's production consists of dairy and livestock breeding. Many of the inhabitants combine seasonal fishing with farming to increase their income. Until the early 20th century, most families on the peninsula, especially around Kilbaha depended almost entirely on fishing as an income, fishing all year round with nets and fishing line making it a thriving local industry (Loop head tourism).

However, the western region of Ireland has suffered from emigration even during the periods when Ireland was experiencing economic growth, and after the economic downturn in 2008 thousands of families have migrated which has resulted in a declining youth populace (Molyneux, 2016). On the county level, the net migration accounts as a contributor to the population decrease (Clare county council). For example, the population in Kilkee, the main village in Loop Head, according to Census 2006 was 1,325 while in 2016 it had decreased to 917 which implies a 30% population decrease in a period of 10 years (Central Statistics Office, 2016)

Besides the decline in population, Loop Head faces other challenges, such as: inadequate public transport services, limited job opportunities and limited number of schools making it not suitable for young families to live in loop head. Although, Loop Head is endowed with renewable energy resources, almost all of the households still depend on fossil fuel as their main heating fuel (Central Statistics Office, 2016). Furthermore, some of the buildings are old with low energy efficiency and low BER rating, hence requiring significant expenditures for heating.

The Loop Head Energy Action Partnership (LEAP) is a community-led project between the International Class (IC) of the Europa Universität Flensburg, the development organizations of Carrigaholt, Kilballyowen and Kilkee, Loop Head Tourism, the Farming Community of the Loophead (Carrigaholt, Kilballyowen and Kilkee parishes), local residents, business owners, individuals and Astoneco Management. The LEAP partnership aims to understand the constituents of the local energy status quo in order to explore possible case studies of prospective energy balances and to help promote the use of sustainable energy resources in the Loop Head community.

The international class team comprises of 13 engineers from the Master programme in Energy and Environmental Management at the Europa Universität Flensburg, Germany and the lecturers of the programme. The IC team in close collaboration with the community partners has the objective to raise awareness in the local community by determining feasible and cost-effective energy related options for the utilization of the current energy resources in the community.

The IC team analysed the techno-economic, socio-economic and environmental aspects of the LH community in collaboration with the community members through interviews, workshops, questionnaires and surveys to ensure apt community engagement and validation of the data collection. Figure 1-1 below shows the main sectoral component of the prefeasibility studies conducted in the Loop Head (LH) community by the IC team.

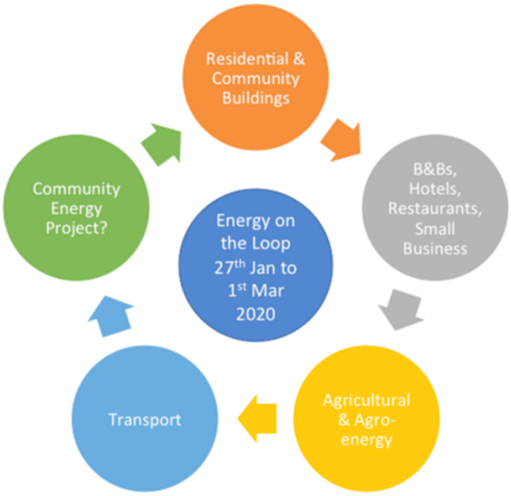


Figure 1-1 Sectoral division of the Loop Head Community (Credit: John Aston)

The IC team evaluated the current energy balance, conducted case studies that could benefit the LH community in terms of energy efficiency measures, renewable energy resources for energy production, reduction in energy import and carbon emissions which could serve as a guide towards a self-sustained rural community.

This report summarizes the following findings: The community engagement processes in terms of conducted workshop and interviews in chapter 2.The status quo of the current energy balance in the LH community was illustrated in chapter 3 while the energy demand for each sectors is analysed in chapter 4.The available renewable energy resources in the community is identified in chapter 5, a Vision for future Loop Head community is elaborated in chapter 6. The policies, grants and regulations governing the execution of community energy projects is elaborated in chapter 7, while prefeasibility studies in the five sectors is explained in chapter 8,9,10 and 11. Lastly, the conclusions and summary are presented in the remaining chapters.

2 Community Engagement

“Community engagement seeks to engage the community in order to achieve long-term and sustainable outcomes, relationships, decision making, discourse or implementation” (PennStateUniversity, 2020). Community engagement had been an integral part of the prefeasibility studies of the team of students from Flensburg. It was very important for the team to understand the challenges, ideas and future aspirations on the energy sector from the community to ensure their engagement and to include their ideas into the prefeasibility studies. In this regard, two workshops in Kilkee Bay Hotel were carried out together with the local partner “Astoneco”. In addition, the interviews conducted for each sector are as follows: 10 interviews in residential, 9 in Agro-farming, 11 in Hotel and B&Bs and small businesses. These interviews also included questions regarding transport and willingness to participate in community energy projects.

The main objective of the technical interviews was to understand the status-quo of energy consumption in the above-mentioned sectors and communities’ needs in terms including transportation. It needs to be mentioned that the interviews are not considered representative due to the small sample size, however they supports to provide general indicators for the work conducted in this research.

Part of the technical interviews included questions regarding the willingness to participate, manage or invest in a community owned renewable energy project. Most of the participants showed interests in being part of a community owned energy project, but express certain concerns in terms of costs and the project locations. Additionally, communities were also asked about the preference technology that they are most likely be in favour of. It was shown that 42% of the group were in favour of AD and 16% were in favour for solar.

The first workshop was conducted on the 1st of February 2020 and received 40 participants from different sectors. The objective of the workshop was to engage with local community, understand the challenges, and extract ideas regarding energy issues. This was achieved by the following five formulated questions:

Table 2-1 Questions for the first Workshop

1.	What are the main energy related problems and opportunities?
2.	What areas does the community of Loop Head want to focus on?
3.	What challenges are in the way to implement energy related projects?
4.	What is needed to be done to enable as many people as possible to be actively involved in energy projects?
5.	What are the recommendations to increase support and benefits from energy projects for all in community?

The Carousel Brainstorming Technique was applied to facilitate the discussion. Five groups of 7 to 8 participants from different sectors have actively participated in discussing above five questions. The main findings of the discussions are presented as follows:

1. What are the main energy related problems and opportunities?

The community presented below problems related to energy from different sectors:

i. Problems with energy efficiency and insulation in residential buildings.
ii. Lack of public transport facility and gas pipeline in Loop Head
iii. Difficulty in slurry management especially during wintertime.
iv. Lack of communication between Loop Head community and Electricity Supply Board (ESB).
v. Lack of knowledge on available grants on different sectors.
vi. Potential environmental impacts caused by energy projects.
vii. High upfront costs for the technologies which seems to be difficult to manage especially for the small family farms in Loop Head.

They have identified not just the energy related problems, but also various opportunities in the energy sector in Loop Head. Different ideas on generating electricity from waste or slurry, electricity generation from renewables and its local use, smart grid projects, electric vehicle for public transport, and job opportunities that new energy projects bring along were identified. Their inquisitiveness for having a pilot project in Loop Head was also noticed.

2. What areas does the community of Loop Head want to focus on?

The interest regarding becoming a sustainable energy community could be observed from the ideas they expressed. The following main ideas were highlighted by them:

i. Upgrading heating systems in old buildings in Loop Head.
ii. Small scale solar and wind farm development.
iii. A prefeasibility study on an Anaerobic Digestor for energy generation.
iv. Energy optimization to reduce CO_2 emissions from buildings.
v. Utilizing existing infrastructure of Money Point power plant for energy related projects.
vi. Study on how projects can provide jobs opportunities.

3. What challenges are in the way to implement energy related projects?

The challenges expressed by the community are as follows:

i. High upfront costs and long payback for the building retrofit and energy projects.
ii. Grant and support schemes may not be enough to support technologies.
iii. Lack of knowledge on the best practices in energy efficiency and energy projects.
iv. Lack of expertise for financial and technical consultation or for the management of the project.
v. Difficulties for deploying centralized systems due to scattered population.
vi. Lack of unbiased and reliable information.

vii. Difficulties for transporting slurry because of lack of enough roads and traffic management especially during summer season.

4. What is needed to be done to enable as many people as possible to be actively involved in energy projects?

Since communities know the socio-economic context, they came up with ideas that could be applied to involve more people in energy projects. The following ideas were suggested by the community:

i. Tailor-made information for specific stakeholders with simplified wording especially for technical terms.
ii. More information on cost and benefits, income, and potential savings for the community and community ownership of the energy projects
iii. More information about different job opportunities and benefits for maintaining population
iv. Involving the youth and senior citizens by utilizing their knowledge and experience
v. Partnerships and collaboration with the Irish Universities and Government advisory for farmers to create stronger network
vi. Transparency on the flow of information and using different communication channels like social media, local newspaper and local TV for media coverage and publicity

5. What are the recommendations to increase support and benefits from energy projects for all in community?

Realizing that the community support is extremely important for the long-term sustainable development, the following recommendations were made:

i. Clarity in goal, structure and pathways with different options for the implementation.
ii. Transparency on the flow of information regarding facts and details.
iii. Partnerships with the existing communities, universities and involvement of community while developing the project.
iv. Engaging organizations of farmers, tourists, etc. during the development of the project.
v. Marketing of the community projects through social media, local TV and newspaper.
vi. Targeting easy and more energy efficient energy projects with proven technologies.
vii. Proper management of the project by tracking milestones and progress.
viii. A diverse steering committee with youth, farmers, and other community members.

The main objective of the second workshop which was conducted on the 8th of Feb 2020 with the presence of 70 participants was to provide information on the existing support and policies for community energy projects and to pass on the experience of a community energy project from Aran Islands. This was achieved by the presentations from Sustainable Energy Authority Ireland (SEAI), Aran Islands Energy Co-op, and Limerick Institute of Technology.

3 Current Energy Balance

Based on census data of 2016, the area under consideration comprises of Small Areas with a total population of 2,567 people. Energy demand is different in each of these Small Areas as well as the share of fuels used for heating. The energy demand of the different building types in Loop Head is approximated using different methods and sources including the Sustainable Energy Authority of Ireland (SEAI) Heat Atlas, SEAI annual reports, census data, interviews and surveys, population and different data available from SEAI. The detailed methodology is explained in the report later in different sections. The total energy demand comprises of heat, electricity, and transportation. The basic sources used for heating are oil, LPG, coal, peat and electricity. All households have individual heating arrangements with 61% having oil boilers. A further breakdown of heat demand is shown in section 4 of the report.

The total heat demand is approx. 26 GWh. This includes heat demand of water and space heating in the residential, services and public sector. The total electricity demand is approx. 18.4 GWh. Most of this electricity is used in the residential sector followed by consumption in the farming sector. There is a demand of diesel in the transport and farming sectors. Total diesel demand is 18.3 GWh for private vehicles and in farming equipment. Below graph shows the breakdown of demand.

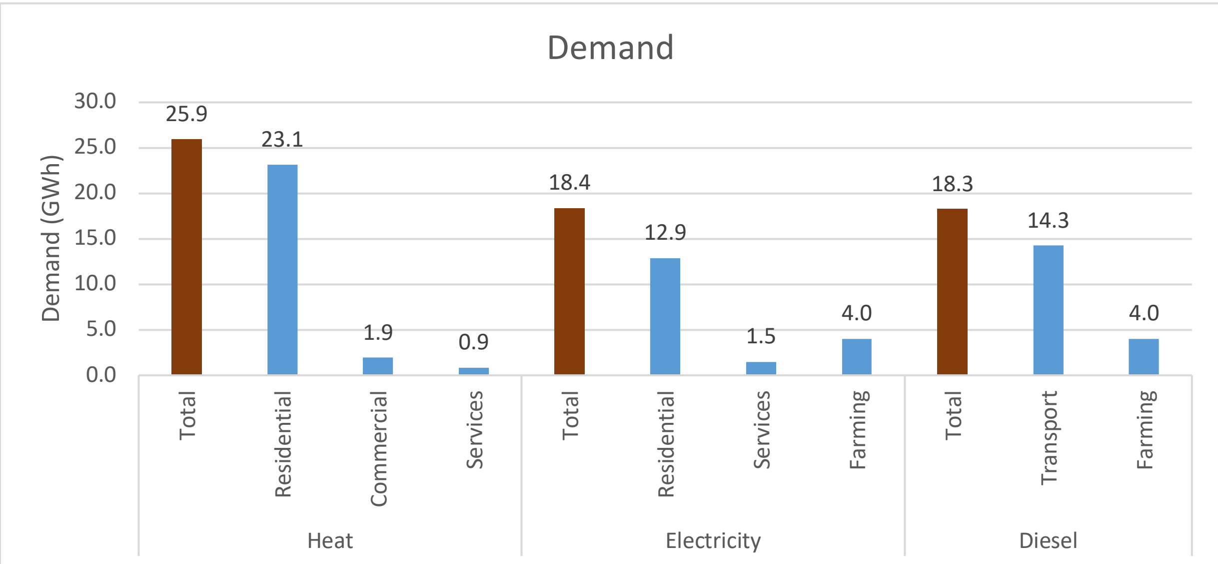


Figure 3-1 Energy Demand in Loop Head, GWh/year

The demand presented above is mostly met by imported sources. All heating coal, oil and LPG, are imported from outside of Loop Head while some quantity of wood and peat are produced locally. There are two wind turbines operating in Loop Head. According to our own simulations, they generate approx. 13.8 GWh of electricity each year which is fed into the national grid.

The electricity generation of the wind turbines cannot presently cover the electricity demand of Loop Head and there is net import of electricity to the area. Currently, wind turbines generate only 22% of the overall energy demand. The imports of different fuels and electricity is shown in below graph.

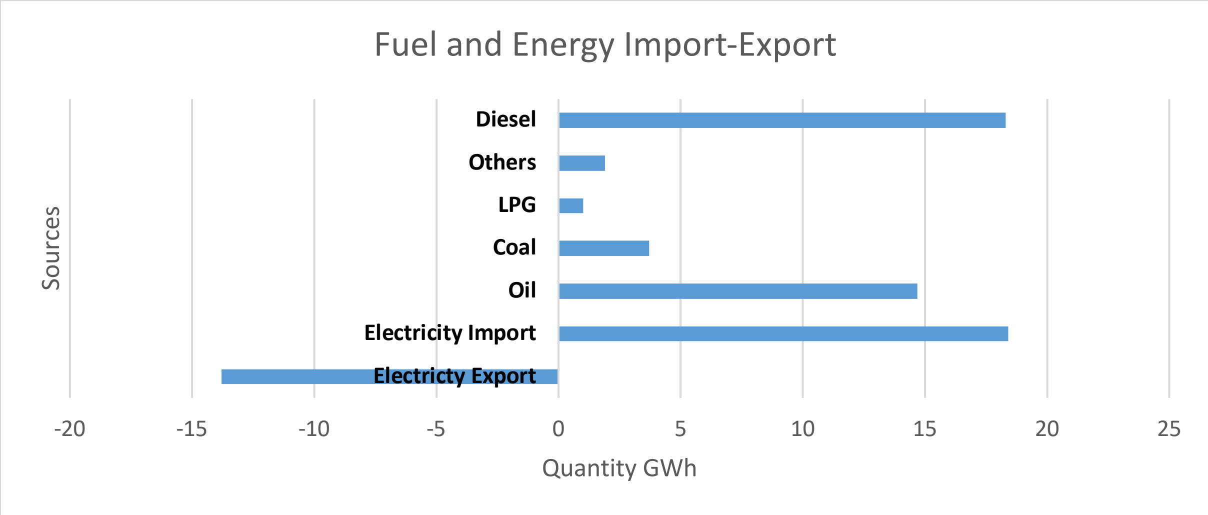


Figure 3-2 Overall Import Export Of energy

Fuels used for energy generation and services have different costs. Annual costs of fossil fuels for heating and transport sum up to approx. €4.5 Mio, whereas electricity import costs approx. €3.7 Mio. So, payments of approx. €7.3 Mio. leave the region annually in exchange of energy services.

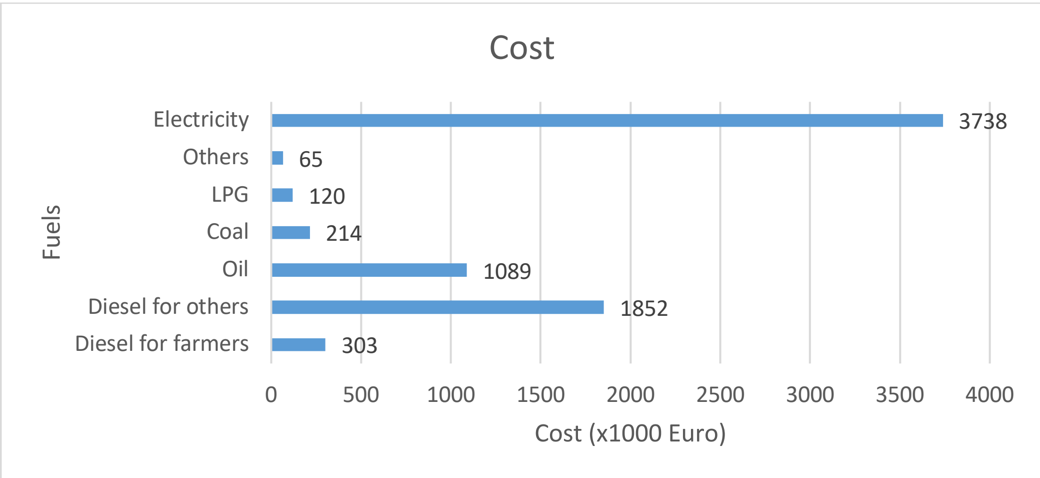


Figure 3-3: Energy Payments

For an individual residential household, it can be witnessed that local communities spend 2,220 Euro annually for heat and electricity demand. This accounts for 4.2 MWh of electricity and 16 MWh of heat demand. In order to meet this heat demand, on average, following share of fuels, efficiencies and quantities are used in each house.

Table 3-1: Fuel share, efficiency of technology and quantities as used for calculations

Fuel	Share	Price/MWh	Efficiency	Quantity of fuel (MWh)
Coal	11%	61	0.74	2.4
Oil	51%	74	0.88	9.3
Peat	23%	11	0.75	4.9
Electricity	8%	137.5	1	1.3
Other	5%	62	0.65	1.2
LPG	2%	132.3	0.95	0.3

4 Sectorial Demand

4.1 Buildings

4.1.1 Residential sector

Information about residential buildings was collected based on statistical data from (CENSUS Statistics, 2016) and from conducted interviews. According to the census, the total number of houses in Loop Head is 2,982 (Table 4-1). In 2016 the population of Loop Head was 2,567 people.

Table 4-1: Breakdown of occupancy status of households in Loop Head (CENSUS Statistics, 2016)

Occupied households	Unoccupied holiday homes	Other vacant dwellings	Temporally absent	Total number of houses
1,071	1,586	276	24	2,982

From the data provided by (CENSUS Statistics, 2016) the highest share of the households are detached houses or bungalows. Figure 4-1 shows the number of occupied houses by constructed year of building. 19% of the house have been built in the five years from 2001-2005, According to interviews with residents this building boom often led to poor quality in building standards.

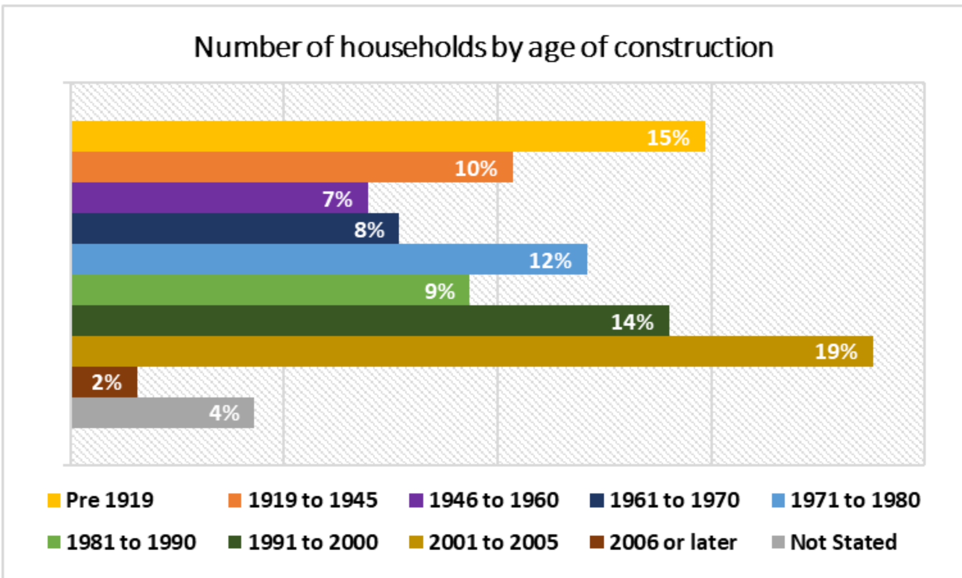


Figure 4-1: Number of households by age of construction in Loop Head (CENSUS Statistics, 2016)

Based on the data of an average number of people per household (from 2 to 3 people/household) and average floor area per person in Ireland (33 m^2/person) (Wilson L., 2014) the average floor area of occupied houses is calculated (from 66 to 99 m^2 per household) (CENSUS Statistics, 2016). Figure 4-2 below illustrates the breakdown of fuel used for central heating in permanent private households in Loop Head (CENSUS Statistics, 2016). From this data, it is observed that the majority of households use oil-fired central heating system and peat-fired system.

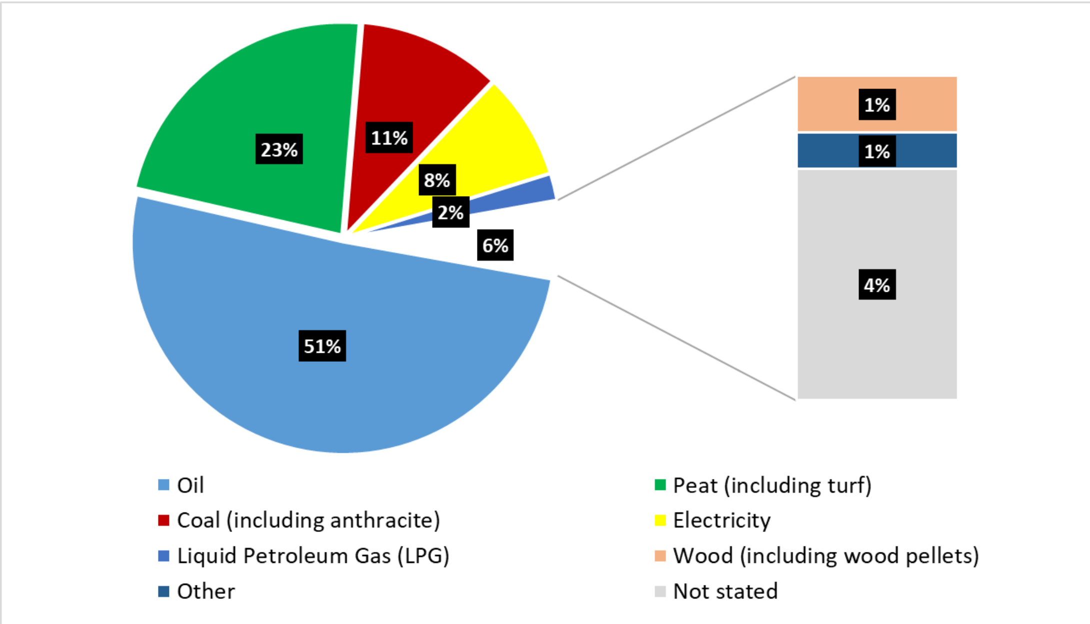


Figure 4-2: Heating technology by fuel type in permanent private households (CENSUS Statistics, 2016)

The estimated monthly heat, water heating and electricity demand for occupied houses are calculated based on the small areas data from (CENSUS Statistics, 2016) and the heat demand atlas (SEAI, 2018). The available data from heat demand atlas is on annual resolution and includes the heat demand per small area without detailed information for each household. In order to estimate the heat demand of each household in Loop Head, a building typology approach based on buildings age classes is used. Based on data from (Central Statistics Office, 2020) the primary energy use of occupied households per building age in each small area is normalized with associated BERs (Building Energy Ratings[1]). The calculated average primary energy use (kWh/m^2/year) of occupied households shows the total heat demand of the house. After the approximate total heat demand per each occupied house is identified, the value of heat demand per each household is adjusted with the total heat demand per small area using a calculated weighted primary energy factor of existing heating technologies. A limitation of this approach is that the distribution of heat technologies for each building age is assumed to be equal. Figure 4-3 shows the calculated monthly space heating demand, water heating and electricity demand for each household. In order to identify monthly heat demand data for each household, the heating degree days analysis[2] is used (Energy lens, 2020). In Ireland a heating base temperature is 15.5ºC and the average annual heating degree days in Loop Head is 1929

[1] A BER is an indicator of the energy performance of a home that shows the energy use for space heating, ventilation, water heating and lighting.

[2] Heating degree days (HDD) are used for calculations that relate to the heating of buildings. The colder the outside air temperature, the more energy it takes to heat a building to a comfortable temperature

HDD (Met Éireann, 2020). The water heating demand of each occupied household is calculated using data on annual heat demand from heat demand atlas (SEAI, 2018), the values of share of water heating from the total heating demand (Heat Roadmap Europe, 2017), the average number of people per household in each small area (CENSUS Statistics, 2016) and a simplified calculation of water heating demand per capita in Ireland (SEAI, 2018).

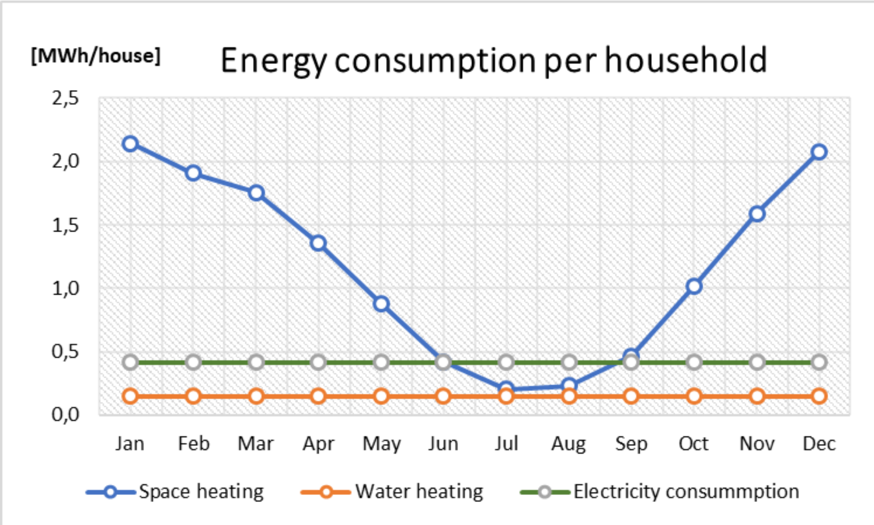


Figure 4-3: Monthly demand of the occupied households of Loop Head (space heating, water heating and electricity)

The electricity demand of each occupied household is calculated based on an average electricity consumption per capita for Ireland (SEAI, 2018) multiplied to the average number of people in the house and number of houses in Loop Head (CENSUS Statistics, 2016). A more detailed description of the space heat and water heating methodology calculation is in Appendix 1.

Based on previously mentioned approaches and calculations, the total heat demand of Loop Head for occupied houses is estimated at 16,762 MWh/year, of which the space heating is 15,188 MWh/year and water heating is 1,574 MWh/year. The highest heat demand is observed in Rahona, Kilkee, Moyarta and Querrin (Appendix 2). The total electricity consumption of occupied houses in Loop Head is 4,410 MWh/year.

4.1.2 Holiday houses

There are 1,586 unoccupied holiday homes in Loop Head, which mainly have been rented during summertime (CENSUS Statistics, 2016). The highest number of holiday houses and holiday flats is located in Kilkee (Figure 4-4).

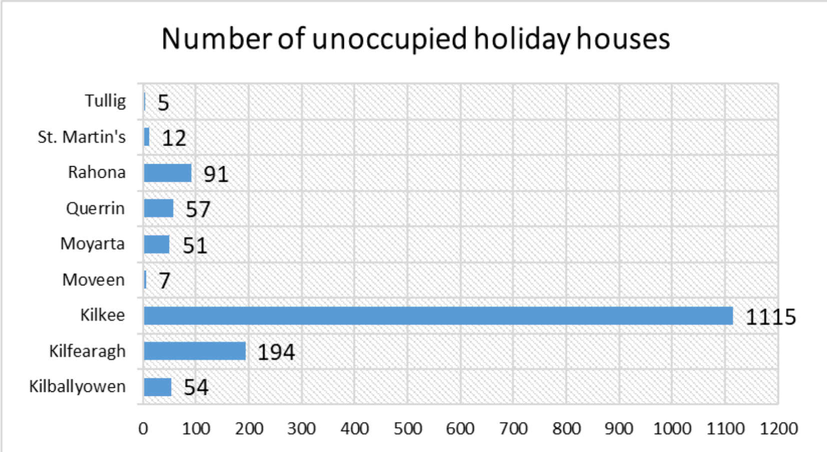


Figure 4-4: Number of unoccupied holiday homes in Loop Head (CENSUS Statistics, 2016)

Following the methodology of calculating monthly demand of the residential sector and assumed occupancy status of the holiday house, the monthly demand for holiday houses is calculated. The estimated heat, water heating and electricity demands of holiday houses have been calculated based on the small areas data from (CENSUS Statistics, 2016), heat demand atlas (SEAI, 2018) and data on occupancy rate provided from interviews with stakeholders in the tourist sector, conducted by commercial sector team.

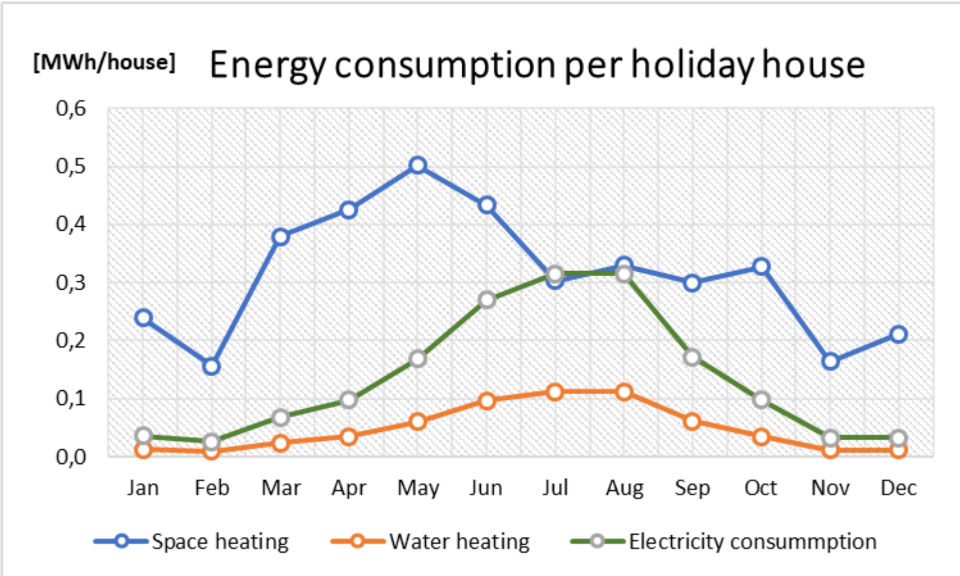


Figure 4-5: Monthly demand of the holiday homes of Loop Head (space heating, water heating and electricity)

Based on previously mentioned approaches and calculations the total heat demand of Loop Head holiday homes is 5,984 MWh/year, of which the space heating is 5,060 MWh/year and water heating is 924 MWh/year. The total electricity consumption of holiday houses in Loop Head is 2,588 MWh/year.

4.2 Commercial sector

According to the SEAI's heat demand map, the total heating demand for commercial buildings in Loop Head is estimated at 3,139 MWh/year. As tourism is one of the main economic drivers of Loop Head's commercial sector, it is relevant to investigate the relationship between heating consumptions related to tourist buildings versus total heat demand of the sector. This is important to provide signals on how much impact any changes in tourism inflow can influence the overall energy demand of the area. In Loop Head, tourism buildings can be separated into:

- Accommodation services (E.g. Hotels, B&Bs)
- Other type of buildings (E.g. Restaurants & bars, Kilkee Water world centre)

To understand and assess the current energy demand of the tourist sector, the research team has carried out a literature review on energy demand in the hospitality sector and combined that with a series of interviews with 2 local Hotels', 6 B&B's, 2 restaurants' owners and Kilkee Water world's manager to validate and collect supporting information (Questionnaire attached at the Annex). For other tourism related buildings which were not interviewed, with limited resources of information, the research team can only make educated assumptions and extrapolations from existing literature information and actual data collected from interviewed buildings.

4.2.1 Accommodation services

Accommodation services play a major role in a tourist's overall experience of visiting a place. It is one of the big components of tourism sector's income (Poudel, 2013). Coming to Loop Head, Peninsula, tourists are offered with diverse options for accommodations including hotels, B&B, and holiday houses. All hotels are located within the central hub of the region, Kilkee while B&B and holiday houses are spread out across the Loop Head Peninsula.

Table 4-2 Number and location of tourist accommodations in Loop Head (Source: Data collected from Census of Ireland and local interviews)

Type of accommodation	Number of buildings	Location
Hotel	5	Kilkee
B&B	18	Kilkee, Kilbaha, Cross, Carriagholt, Querrin

By interviewing 2 out of 5 hotel managers and 6 out of 18 B&B's owners, combining that with literature study on hotel energy consumption in Europe and assessing the size of hotels and B&Bs that could not be interviewed, it is assumed that hotels in Loop Head consumes on the average 352 MWh of energy annually (72% and 28% for electricity and LPG, respectively). Due to lack of further information it was also assumed that the hotels consume liquefied petroleum gas (LPG) as predominant fuel for central heating systems (Some hotels' heating supplemented their heating demand with electrical radiators). The share between LPG and electricity consumption for heating are estimated at 63.5% and 36.5%, respectively. Major energy demand is coming from their electricity consumption for electrical appliances, offices and ventilation, accounting for 46% of the total energy consumption while that of space heating is at approximately 31% (See Figure 4-6).

On the other hand, an average size B&B[3] in Loop Head consumes only 22 MWh of energy per year, for which heating accounts for 83% of total energy demand (62% for space heating and 21% for water heating). Most B&Bs and holiday houses are using oil with supplements of coal or turf/peat for furnaces as heating fuels. Many B&B have AGA range cookers with an option to produce central heat. Large quantities of fuels for heating are purchased from regional suppliers (E.g. in Ennis or Limerick) except for turf/peat which is produced locally from farms[4].

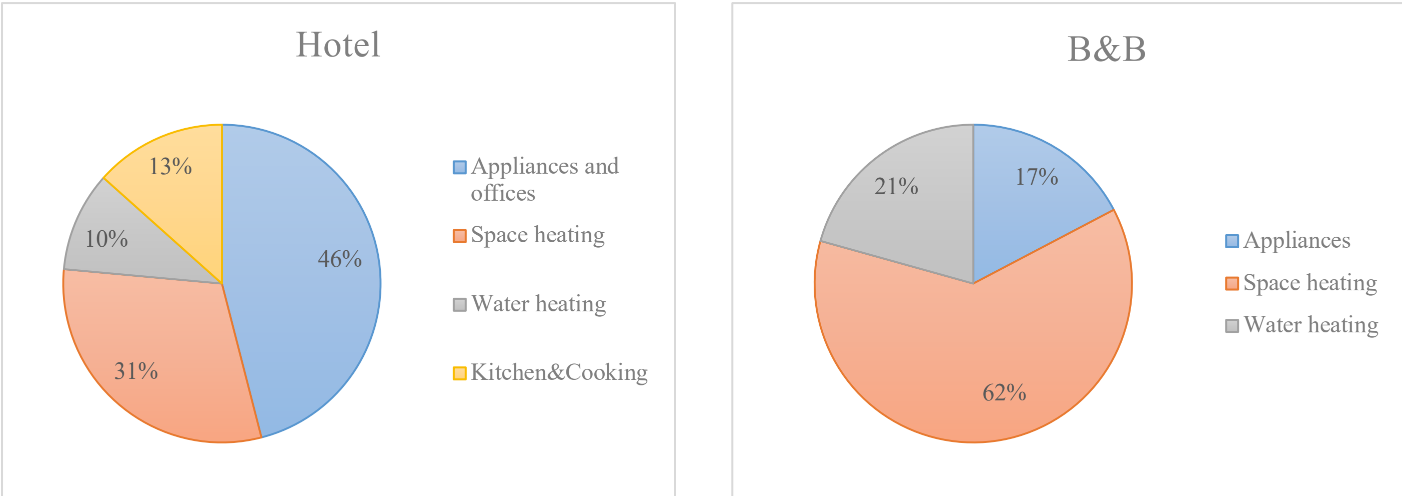


Figure 4-6 Breakdown of energy consumption in Hotels and B&B in Loop Head

In total, the accommodation sectors consume approximately 1376 MWh of electricity, 516 MWh of LPG, 284 MWh of oil and 100 MWh of peat/turf every year. The total heating demand is estimated at 1100 MWh/year, equivalent to 35% of total commercial heating demand. The consumption of fossil fuel for heating results into approximately 687 and 205 tons of CO_2 emissions every year coming from Hotels' and B&B sector, respectively.

4.2.2 Other types of buildings

Apart from residential and tourist accommodations, the research team also conducted interviews with 2 local restaurant owners to understand the energy status of local restaurants. It can be assumed from the interviews that a restaurant in Kilkee consumed approximately 1.05 kWh of electricity and 0.5 kWh of gas per guests. In total, the restaurant consumes 43 MWh of electricity and 21 MWh of LPG every year. However, there are no clear breakdowns on energy consumption structures yet. The monthly distribution of the energy demand of restaurant throughout the year is highly influenced by its customer occupancy rate, with high season during summer months and December (Due to Christmas holiday) (See Figure 4-7)Also

[3] Aggregated data coming from 6 interviews with local B&B

[4] Combustion process of peat/turf has a low efficiency and produces high amount of emission (E.g. smokes an particulate matters)

the opening times during season and off season vary, which makes a good assumption on the energy consumption of restaurants difficult.

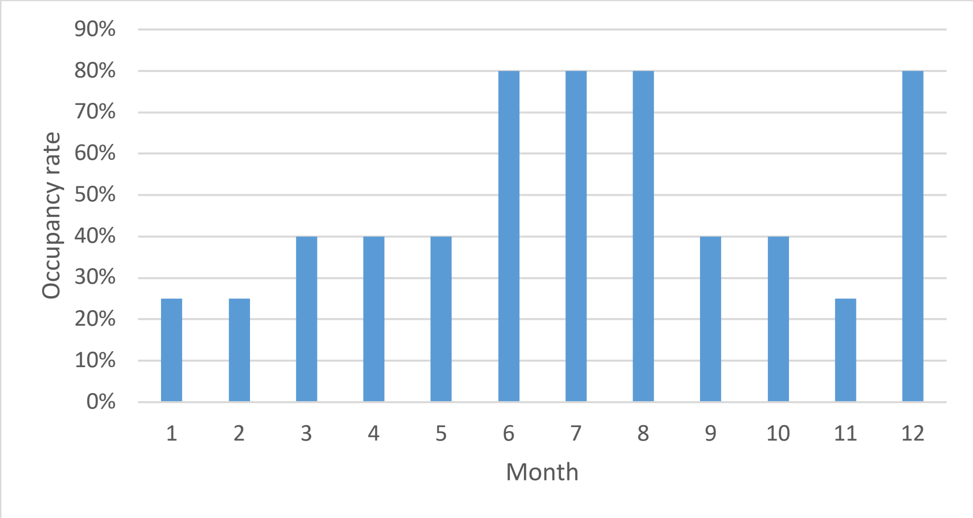


Figure 4-7 Example monthly occupancy pattern from an interviewed restaurant in Kilkee

One of the biggest heating consumers in Kilkee is the Kilkee Water World centre. This is an indoor swimming pool with geysers and gushers, bubbles and whirlpools for local people and tourists. The interview with the centre's manager suggests that the place is only opened for 3 months every year, from June till August with the whole heating system running on an oil boiler (Boiler's efficiency at 89%). The total indoor flooring area of the building is estimated at around 1235 m^2 (Rough measured from google satellite image, applying a factor of 0.95 to account for the footprint of walls). In total, the Water world consumes 17,000 litres of oil every year and spends €19,000 for electricity for 3 month in operation. By converting above data into energy, the total annual electricity consumptions of Water World is estimated at 135.8 MWh and the demand for heating is at 147.8 MWh.

There is also another swimming pool in town, located nearby Kilkee Bay Hotel. The swimming pool is estimated at 590 m^2 ground floor area[5] and is currently closed. There are discussions whether this swimming pool should be opened again. However, with the regulation that each city can only have one operating pool receiving funding from the state, it is unlikely that Water world and Kilkee swimming pool are operating at the same time.

There are already anticipations whether Water World can expand its operating season to 6-12 months or to be converted into a fitness centre and open the swimming pool near the Kilkee Bay hotel for year-round operation. In any of these cases, the two buildings will first be under retrofit to become more energy efficient[6] before opening for operation. The assessment of

[5] Size of the two pool centre are measured by google map with a factor of 0.95 for indoor floor area estimation.

[6] Heat consumption of an optimized swimming pool amounts to 350 kWh/m² floor area while that for electricity consumption is at 208.1 kWh/m². In term of fitness centre, a benchmark for electricity consumption is at 78.4 kWh/m² while that for heating is at 209.3 kWh/m²

energy demand for the different options for the future use of the two swimming pools are presented in the figure below[7]:

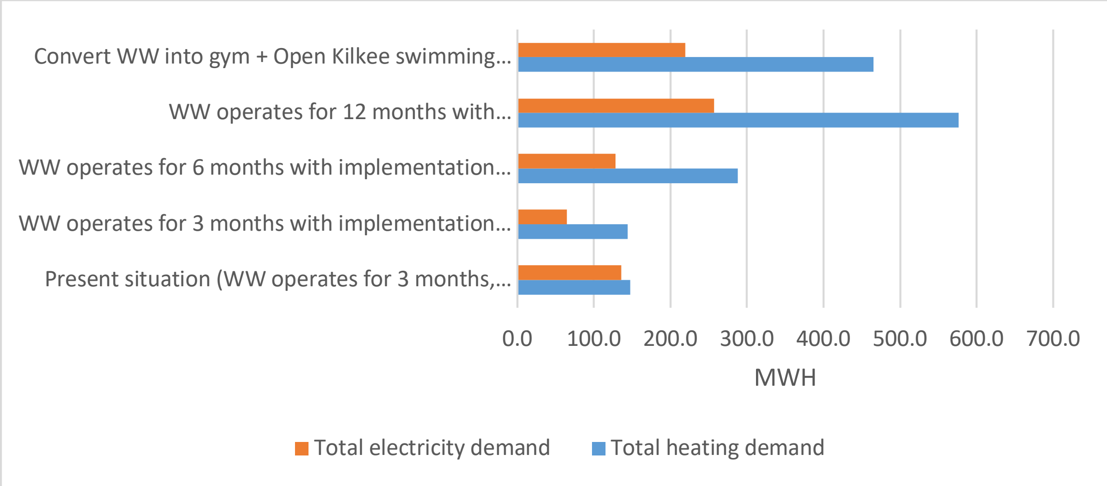


Figure 4-8 Assessment of energy demand for different scenario of Water world and Kilkee swimming pool

By subtracting the part for accommodation services and the water world from total Loop Head commercial heating demand, there is 1,777.5 MWh heating demand remaining (Accounting for 60.3% of total commercial heat demand). These are coming from other services and public buildings such as Cafés and bars, shops, schools and offices. It would require further efforts to identify and breakdown energy consumption in these areas.

4.3 Farming sector

Agriculture is one of the major economic activities in Loop Head Peninsula. There are great differences in energy consumption between counties which is attributed to, livestock species and types of production system (Veermäe, 2013). Energy balance calculations can help to understand the energy flows in the farm to help find ways of saving energy. According to conducted interviews, local farming activities include Beef Farming, Dairy farming, calving, suckling and growing grass for feedstock. A high consumption of Diesel in most of the farming activities comes from the cutting of grass either by contractors or on farm tractors. Electricity consumption is particularly higher on Dairy farms.

4.3.1 Methodology for electricity demand calculation

A total of 9 farmers where interviewed across the peninsula with a representation of small scale, medium- scale and large-scale farms. This was done to give a general representation of the productive use of energy on farms. Table 4-3 below illustrates a summary of the results from the interviews.

Table 4-3 Summary of Interview Results on Energy Demand, Source: Interview responses and Author data analysis

[7] The heating and electricity demand as calculated based on the benchmark for optimized swimming pool and fitness centre (Mentioned above) with consideration for total in door ground floor areas for the two buildings.

Farm Visited	Agricultural Activity	Hectares Under Cultivation	Livestock (bulls, cows, calves	Diesel Consumption per year	Electricity consumption kWh/ Month	Diesel Expenditure per year (Euros)	Electricity Expenditure Euros/ Month	kWh/Cow/week
Farm 1	Cattle (beef Production)	30	80	1500	754	1125	110	2.36
Farm 2	Cattle (beef Production) and Suckling	35	70	1500	892	1125	130	3.18
Farm 3	Dairy	89	162	2000	2058	1500	300	3.17
Farm 4	Cattle	141	320	25000	3429	18750	500	10.07
Farm 5	Dairy	35	56	3000	792	2250	180	3.54
Farm 6	cattle	17	25	2000	705	1500	160	7.05
Farm 7	Dairy	20.2	85	5000	3772	3750	559	11.09
Farm 8	Dairy	80.9	180	1000	4115	750	600	5.7
Farm 9	Dairy	56.6	70	2500	1948	1875	284	7

The highest electricity consumption was from a dairy farm, farm number 8, indicated by a consumption of around 4,115 kWh per month due to dairy farming activities such as milking using a milking robot system. A research study carried out by (Upton, 2010) on 3 research farms indicated that most Irish dairy farms have the high electricity demand compared to beef farms, though in some cases this can be different. This emanates from milk cooling which is the largest consumer of electricity at 37% followed by water heating 31%, vacuums pumps 19% and lighting 10% (Upton, 2010). Farm number 7 has the second highest electricity consumption of approximately 3,772 kWh/month, this may be attributed to a high number of cattle pegged at 320 thus a high energy demand. Moreover, Diesel consumption was also higher in farm 4 (25 000 litres) this farmer also contracts and carries out farming activities such as silage cutting for other farms thus high Diesel consumption. The calculation of expenditures for Diesel was based on the price of green diesel at 75cents per litre as indicated by most farmers during the interview. Calculations for electricity consumption were based on the pricing of electricity which has a night rate and a day rate pegged at 6.75 cents/kWh and 14.85 cent/kWh respectively and a PSO levy of 3.48 € / Month. This data was captured from the electricity bill of one of the farmers during the interview.

The cost of electrical energy might increase dramatically in the future and awareness of energy consumption on farms would be valuable (Upton, 2010). In order to understand the electrical energy for farms in Loop head, data for Small Areas demarcation based on the 2010 census (StatisticsOffice, 2010) was analysed. This includes the number of livestock in each small area namely Kilballyowen, Kilfearagh, Moveen, Moyarta, Querrin, Rahona, St Martins's and Tullig**.** The methodology used to calculate electricity demand for these small areas was based on the interviews from 9 different farms. The electricity consumption was calculated with E/EP where:

E= Electricity expenditure

EP=Electricity price

In order to obtain the kWh/cattle per month, monthly electricity consumption was divided by the number of livestock the farmer owns in accordance to either beef or dairy cattle. Results show an average of 15.27 kWh/cattle/ month for Dairy cattle and 24.38 kWh/cattle/ month for beef cattle. This was done to make a comparison between the indicator obtained from literature review , which varies from 4kWh/cow/week to 7.3kWh/cow/week for dairy cattle. This is equivalent to around €0.60/cow/week to €1.10/cow/ week (Upton, 2010) Teagasc which is the Agriculture and Food Development Authority of Ireland. Summary of results show that the average consumption was 3.8kWh/cow per week for beef cows and 6.05kWh/cow/week with indicative figure shown in Table 4-3 for each farm.

The same methodology was adopted for calculating the diesel consumption of a cow per month and year. The results indicate that diesel consumption for dairy cattle is around 33 litres/cow/year and 15.27 litres/cow/year for beef cattle. This translates to total consumption of 236, 731 litres/year for Dairy cattle and 159,905 litres/year for beef cattle. This is in line with literature source for Irish farms (Upton, 2013).

4.3.2 Electricity demand by Small area (farms)

The total number of cattle in the aforementioned regions amount to 14,130 cattle. This number was obtained from the local farmers, with comparison with national Census which presents a total number of 17,601 cattle (StatisticsOffice, 2010). The total livestock was considered with differentiation between cattle for beef and for Dairy combined with an assumption that the number of cattle is constant throughout the year. This assumption was considered because the rate at which livestock number changes per year could not be obtained. The Figure 4-9 below illustrates the Electricity demand by small areas for Dairy and Beef Cattle. The highest electricity demand is in Kilbayowen. For both dairy and beef cattle, the total electricity consumption is approximately 500, 000 kWh/year and 420,000 kWh/year respectively. Tullig and Rahona have slightly the same electricity demand for dairy cows which is around 320,000 and 310,000 kWh /year, respectively. However, there is a significant difference for beef cattle in these two small areas, Tullig has around 241, 000 kWh/year and Rahona with 310,000 kWh/year. Querrin and St. Martins have the lowest electricity demand of around 150,000kWh/year and 144,000kWh/year for Dairy cattle and 127,000kWh /year in Querrin and 148,000kWh/year for St. Martins under the category of beef cattle. The disparity mentioned above may be attributed to a high count of livestock in Kilballyowen as compared to other small areas on the peninsula.

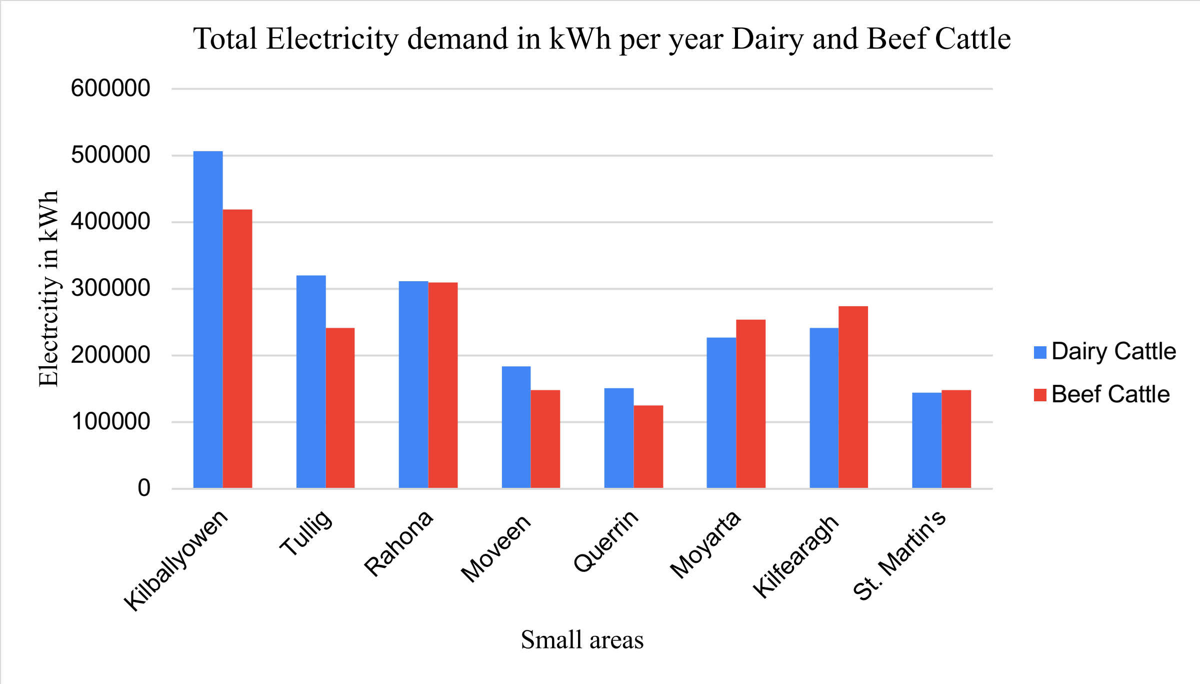


Figure 4-9: Total Electricity demand for Farms (Dairy and Beef Cattle) in Loop Head. Data source: obtained from Census Agriculture Map 2010 *and local farmers.*

The disparity mentioned above is attributed to a high count of livestock in Kilballyowen as compared to other small areas on the peninsula. The plotted electricity demand show that dairy cows generally have a higher electricity demand as compared to beef cattle. This due to the processes carried out on the farm such as milking and washing the cattle's udder with hot water before the milking process. According to (Upton, 2010) heating of water is a substantial energy input in the operation of a dairy farm. Moreover, electricity used by water heating equipment can add up to 2 kWh per cow per week. A clear diagram which shows the highest energy consumers for dairy cattle is shown below. These results are from an electricity audit carried out on three Teagasc Research Farms. This will be reflected in the prefeasibility studies for a farm that uses a robot milking system.

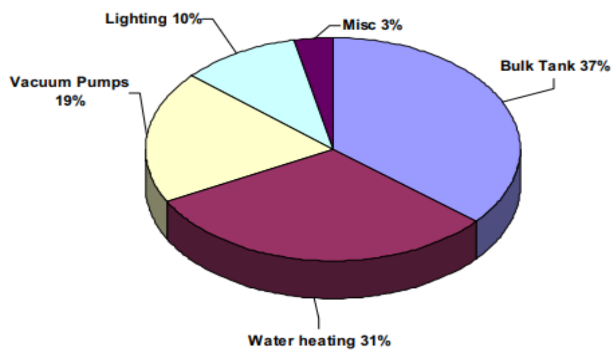


Figure 4-10: Summary for Electricity Audit done on three Teagasc Research Farms. Source: Dairy Farm Energy consumption, Teagasc 2010

4.3.3 Diesel Demand for Small Areas

This section discusses about for diesel demand from small areas. Figure 4-11 indicates a high demand in Kilbayowen around 57,000 litres followed by Tullig of 35,000 litres. The lowest diesel demand is identified in Querrin of around 18,000 litres. This also shows a correlation between the number of livestock and diesel demand. The higher the number of cattle, the higher the diesel demand.

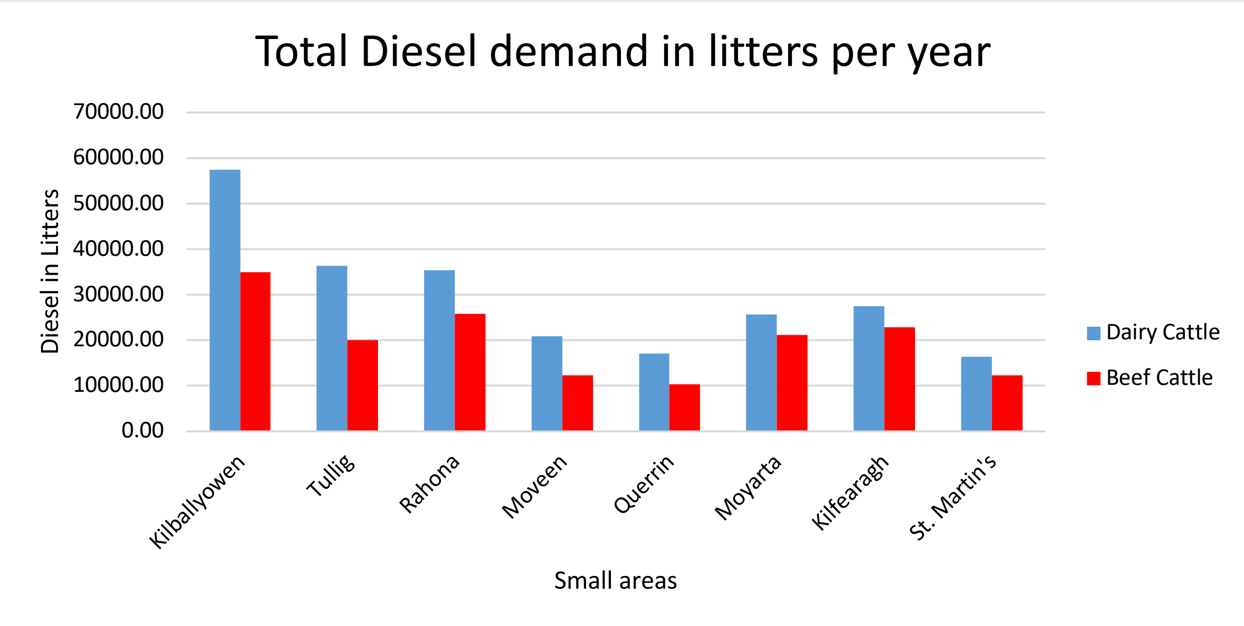


Figure 4-11: Diesel Demand in Litres per year for Dairy and Beef Cattle. Data source: Census Agriculture Map 2010 and Data collected from local Farmers.

4.4 Transport

Transport in Loop Head is heavily dependent on imported fossil fuels. The main form of transport for the local residents in Loop Head is private cars with an estimated total number of 1,200. This figure was calculated based on the total population in Loop Head given from the national Census of 2016 (Estimated at 2,564) (CSO, 2016) and a factor of 0.47 cars per person, calculated from the population and the total number of registered cars in County Clare (CSO, 2016).

Based on these parameters, an average fuel consumption of 0.06 litres per km and the average kilometres driven per year, which according to the Central Statistics Office of Ireland in 2016 was 19,446 for County Clare (CSO, 2016) ; the total estimated Diesel demand for private cars in Loop Head is 1.4 million litres per year. Considering a price of 1.32 € per litre of diesel, the total fuel cost is around 1.85 million Euros per year.

Taking into account the energy content of 10.17 kWh (SEAI, 2017) per litre of diesel, the equivalent energy demand is 14,244.67 MWh per year.

Considering an emission intensity of 2.68 kg of CO_2 per litre of diesel (SEAI, 2017), the estimated total emissions are around 3,759 ton of CO_2 per year. Continuing growth in transport activity will create increasingly challenging conditions to meet climate-related targets.

Table 4-4 summarizes the results for private transport in the Loop Head area:

Table 4-4: Results summary of private cars for Loop Head area

Parameter	**Value**	**Unit**
Total diesel demand	1.40	Million l /year
Annual energy equivalent demand	14,244.67	MWh/year
Total cost of diesel	1.85	Million €/year
Total CO_2 emissions	3,759.17	ton CO_2/year

For Public transport, there is the option of the Clare Accessible Transport (CAT) also known as Clare Bus, a registered charity and Not for Profit community based company that has provided transport since 2003 for Clare and parts of south Galway (Clare Bus, 2020).

In the Loop Head area the service currently operates 2 days a week, on Wednesdays and Fridays and 2 times per day. The main stops are Kilrush, Kilkee, Carrigaholt, Kilbaha and Cross and the request stops are Doonaha, Rehy, Fodera, Fehard, Moveen and Loop Head (Clare Bus, 2020). The current tariff for the peninsula is 2 Euro per ride. In 2019 the total passenger trips were 1,764, where the purpose of use of the service was approximately 90% for shopping, 8% for health and 2% tourism (Ward, 2020).

Most passengers from the Peninsula area go to Kilkee or Kilrush and most passengers from Kilkee go to Kilrush (Ward, 2020).The annual kilometres driven by the minibus annually in the Loop Head area is 13,200 (Ward, 2020).

Based on the same parameters mentioned above for the frequency of the bus, price of diesel, energy content, emission intensity and 13,200 km driven on average per year; the annual estimated diesel demand for the Clare Bus in Loop Head is 1,584 litres with a fuel cost of around 2,094 Euros; the equivalent energy demand is 16.11 MWh per year and the estimated total emissions are around 4.25 ton of CO_2 per year.

Table 4-5 summarizes the results for public transport in the Loop Head area:

Table 4-5: Results summary of public transport for Loop Head area

Parameter	**Value**	**Unit**
Total diesel demand	1,584	l /year
Annual energy equivalent demand	16.11	MWh/year
Total cost of diesel	2,094	€/year
Total CO_2 emissions	4.25	ton CO_2/year

It is important to point that due to the lack of data, in this section, transport of goods, mail service, transport of fuels, etc. is not considered. Agricultural transport is considered as farming demand if farm own vehicles are used.

5 Resources

5.1 Solar

Photovoltaic solar energy (PV) will play a key role in the future global sustainable energy system, it has shown impressive worldwide growth in terms of the scale in deployment, cost reduction, and performance improvement over the last decade (C.Sinke, 2019). To define suitable area and precious estimation on solar potential resources is a vital prerequisite for any successful solar project.

This section evaluates solar energy resources and potential in Loop Head Peninsula and expect to provide information for the community to understand better about solar PV potential in Loop Head, which supports people when investing into solar PV and harvest energy potential from the Sun. The section will investigate the feasibility of employing photovoltaic technologies in Loop Head in order to supply pillar sectors in the community such as residential, B&B, & farming.

5.1.1 Solar irradiation in Ireland

Solar PV systems use the photovoltaic effect to convert solar radiation to electric energy, therefore they can utilize diffuse radiation on overcast days. Solar panels can still produce 10–25% of their typical output on a cloudy day (Richardson, 2018).

Figure 5-1 displays the mapping of the specific yield on the Loop Head peninsula which is the ratio between total annual energy produced and the solar installed capacity. Likewise, it refers to how much energy (kWh) will be produced per day for every KWp of solar modules installed Including efficiency (Santos, 2018). On Loop Head, a PV plant of 1 kWp will produce between 934 and 967 kWh per year.

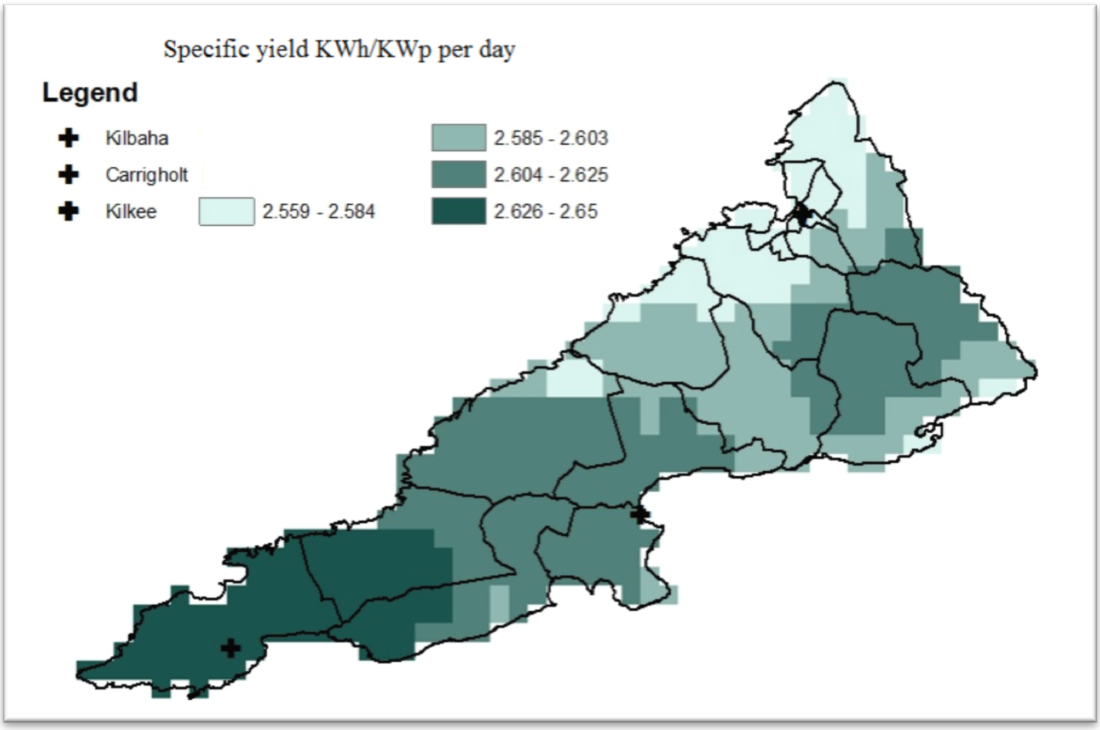


Figure 5-1 Solar resource mapping of Loop head peninsula (Global Solar Atlas, 2019)

As shown in the figure above the dark green regions (Kilbaha) are the regions with the highest average daily specific yield ranging between 2.62KWh/KWp to 2.65KWh/KWp. This range is higher than the average value of Ireland which is 2.51 KWh/KWp as obtained from (Global Solar Atlas, 2019).

5.1.2 Monthly solar irradiation

Global Horizontal Irradiance (GHI) is the actual amount of solar energy radiation on the horizontal surface. It includes the radiation that is directly received from the sun (direct irradiance) and the radiation that is scattered by the atmosphere and clouds (diffuse irradiance).

For each month from 2005 to 2016, daily data on solar irradiation has been retrieved from the European solar energy platform PVGIS (© European Union, 2001-2020), (Huld T., 2012). The chosen location is with the coordinate (Lat: 52.630, Long: -9.690). Based on these data a 10-year average (2005-2016) of monthly global horizontal and at the optimal angle (39°) irradiation has been calculated; see Figure 5-2).

Figure 5-2 reveals that the global irradiation at optimum angle 39° in Loop Head is maximum in May & June with 146.53 KWh/m² and minimum in December as it does not exceed 30.13 KWh/m², otherwise, the electricity demand will be covered mostly in March to September (7 months).

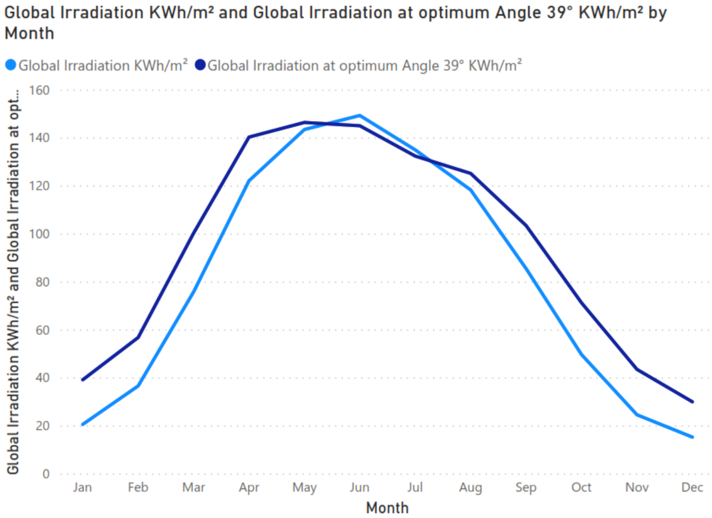


Figure 5-2 Average Monthly solar irradiation estimates (own calculation from (PVgis5, 2016))

Month	Global Irradiation KWh/m²	Global Irradiation at optimum Angle 39° KWh/m²
Jan	20.72	39.30
Feb	36.74	56.92
Mar	75.90	100.39
Apr	122.24	140.43
May	143.59	146.53
Jun	149.43	145.15
Jul	135.09	132.51
Aug	118.40	125.29
Sep	85.62	103.56
Oct	49.80	71.37
Nov	24.72	43.64
Dec	15.41	30.13
Total	**977.65**	**1,135.21**

Figure 5-3 Average monthly Global horizontal and Optimal angle (39°) irradiation (own calculation from (PVgis5, 2016))

5.1.3 Solar energy potential in different sectors

Solar photovoltaic panels (PV) can be installed in residential, commercial or Agro-farming sectors as systems, generating electricity for self-consumption and feeding it to the grid in case of surplus. Moreover, solar photovoltaic technology can be used also on a large scale as solar farms that provide power to the electricity grid and become part of the utility's energy mix.

A first rough estimation of the technical potential for solar PV systems in Loop Head reveals that the residential sector could theoretically generate 12,715 GWh/year from rooftop solar PV systems.

This is based on the following available data and assumptions:

- The total number of occupied households in the area of study is estimated to be 1,071 buildings (Statistics, 2016)
- The average rooftop area for a household is 120m²
- 50% rooftop covering ratio

- The rooftop inclination is 25°
- Global irradiation at an angle 25°: 1,150.43 kWh/m²/year (own calculation from (PVgis5, 2016) for location in [Lat: 52.630, Long: -9.690])
- 20% efficiency for photovoltaic panels
- 14% system loss

Solar potential in agriculture sector

In the agriculture sector, installing photovoltaic panels on Livestock sheds is a promising solution for integrating solar energy because most farms are isolated and located in good geographical locations where shadow impacts are low. Moreover, it can be an opportunity to provide an additional source of income to farmers by reducing the electricity bills.

According to our calculations, the agriculture sector has the potential to generate annually using solar photovoltaic energy approximately 11,789 MWh.

The following data and assumptions were used:

- Total number of livestock in the area is 17,601 (Central Statistics Office, 2010)
- The average shed area for one livestock is 6.77 m² (calculation from interview)
- 50% rooftop covering ratio
- Cowsheds inclination 25°
- Global irradiation at angle 25°: 1,150.43 Kwh/m²/year (own calculation from (PVgis5, 2016) for location in [Lat: 52.630, Long: -9.690])
- 20% efficiency for photovoltaic panels
- 14% system loss

Moreover, regarding solar farms in Ireland, there is more than 1GW of solar photovoltaic with planning permission, and more than 1.5GW with grid contracted or in process, all is ready to progress if there is aid with financial support schemes (Cadogan, 2019). In Loop Head, a solar farm with a capacity of 5MWp built as a community-owned energy project can produce 4.6 GWh every year.

To sum up, Loop Head Peninsula has roughly a total electricity demand of 18.4 GWh, and a potential available area from rooftops in residential and agriculture sectors equivalent to 0.247 Km², which give the possibility to install 23.52 MWp of solar photovoltaic energy (assuming the ratio power per area 190Wp/m² and a covering ratio of 50%) requiring a total investment of 28.224 million Euros (1200Euros/kWp).

5.2 Wind

Ireland has a huge potential of wind energy with favourable wind conditions making it the largest and the cheapest source of renewable energy. The country has a great potential of both onshore and offshore wind energy. It is estimated that in the Republic of Ireland, the overall potential capacity in 2050 will be at 46 GW of which 16 GW are onshore wind farms and 30 GW are offshore wind farm (ABO-Wind). In 2018, wind energy in Ireland provided 85% of renewable electricity and 30% of the electricity demand (SEAI, Wind Energy). By 2018, around 3.6 GW of onshore wind energy was connected to the grid of Ireland (ABO-Wind).

Figure 5-4 shows the onshore wind resource in the Republic of Ireland at the hub height of 100m.

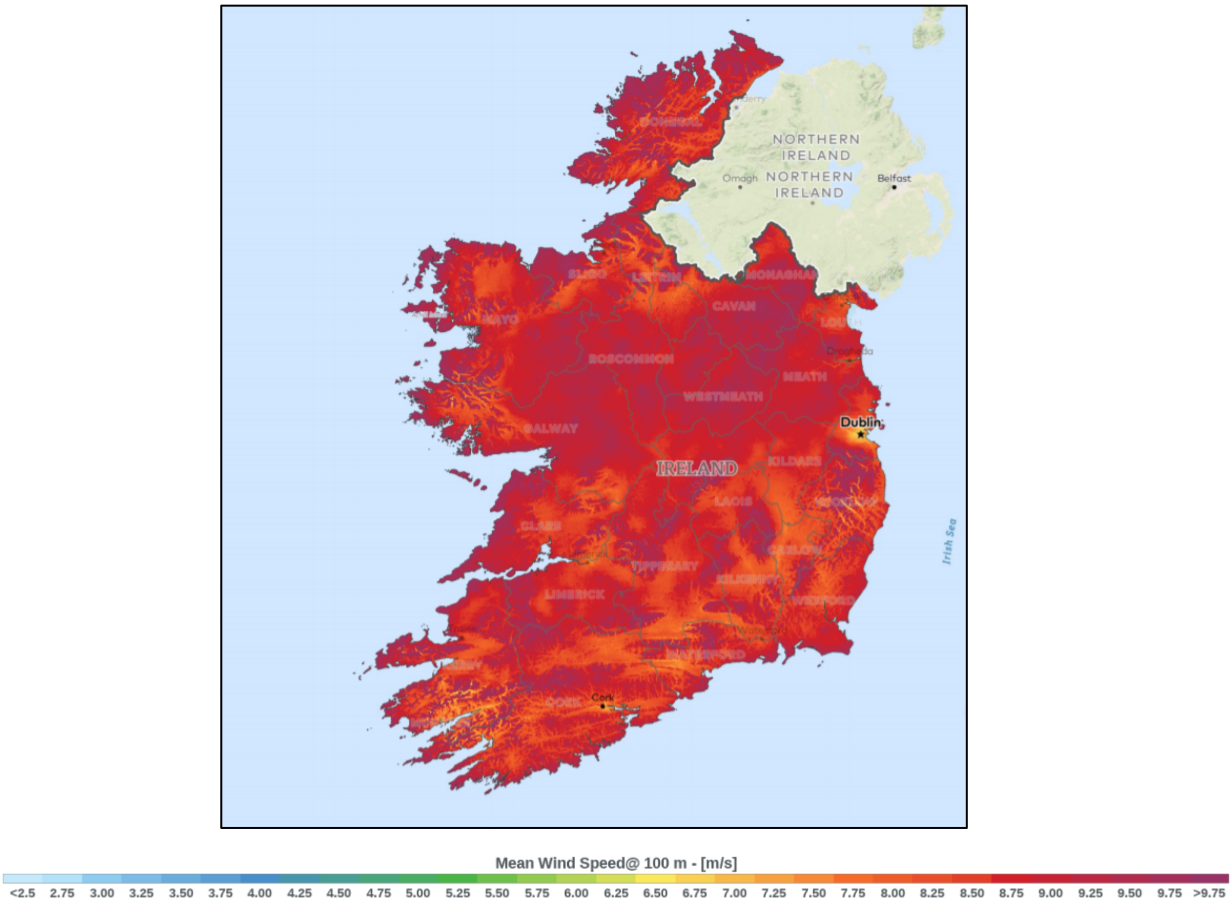


Figure 5-4 Wind Resource Map in the Republic of Ireland (GlobalWindAtlas, 2019)

5.2.1 Wind Resource Potential in Loop Head

The Loop Head Peninsula is on the west coast of the county Clare and is surrounded by the Atlantic Ocean on the northern and western side and on the south by the River Shannon Estuary. Wind resource potentials in terms of specific wind energy (kWh/m^2/year) and wind speed (m/s) in Loop Head was analysed to look on the possibility of developing wind generation as a community project.

Methodology

WindPRO computer software with WAsP interface was used to calculate the wind resource potential in Loop Head. The software conducts a wind data analysis, calculates the energy yield, uncertainties and environmental impacts. Using WindPRO, data on roughness classes and terrain contours have been generated considering the effect of the roughness of the landscape (i.e. presence of grasses, trees, building, etc) and terrain contours on wind speed. Data on roughness classes and terrain are attached in Appendix 5 and Appendix 6. Elevation data was generated as it is required for calculating the energy yield and is attached in Appendix 7. The calculation has been based on the long-term correction of the short term data of one-year (2018) from EMD ConWX[8] mesoscale model to 30 years (1990 to 2019) long term reanalysed climate data "ERA5 (Gaussian)[9] data" using Measure-Correlate-Predict, MCP module in WindPro software. For correlation, hub height of 100m has been chosen as both, the long term and short-term data were at 100m hub height. The correlation calculation has been attached in Appendix 8. Using correlated data, mean wind speed, annual energy yield, noise and shadow have been calculated.

Resource Potential

The average wind speed in Loop Head after correlation is 9.2 m/s at the hub height of 100m above ground level. Wind speed distribution, and its frequency of occurrence are attached in Appendix 9.

Using elevation, roughness, height contour data and wind statistics, the wind resource potential was analysed for Loop Head to find out what amount energy could be harnessed. A hub height of 59 m was chosen as this is the hub height of the existing "Carrownaweelaun Wind Farm" in Loop Head (SEAI, SEAI Wind Mapping System).

The wind speed is varying from 7.6 m/s to 10.8 m/s at the hub height of 59 m as shown in Figure 5-5. The minimum energy that can be harnessed per m^2 of the rotor area per year is 4,173.2 kWh as shown in Figure 5-6.The maximum wind energy potential per m^2 of the rotor area per year is 12,237 kWh when there are year around favourable wind conditions of around 10.8 m/s at the hub height of 59m.

[8] The EMD ConWX meso scale model is run at a spatial resolution of 0.03°x0.03° or approximately 3x3 km with hourly temporal resolution. Sample time series from dataset of such model covers one full year.

[9] ERA5 (Gaussian Grid) is a climate reanalysis dataset developed through the Copernicus Climate Change Service (C3S) and processed/delivered by ECMWF.

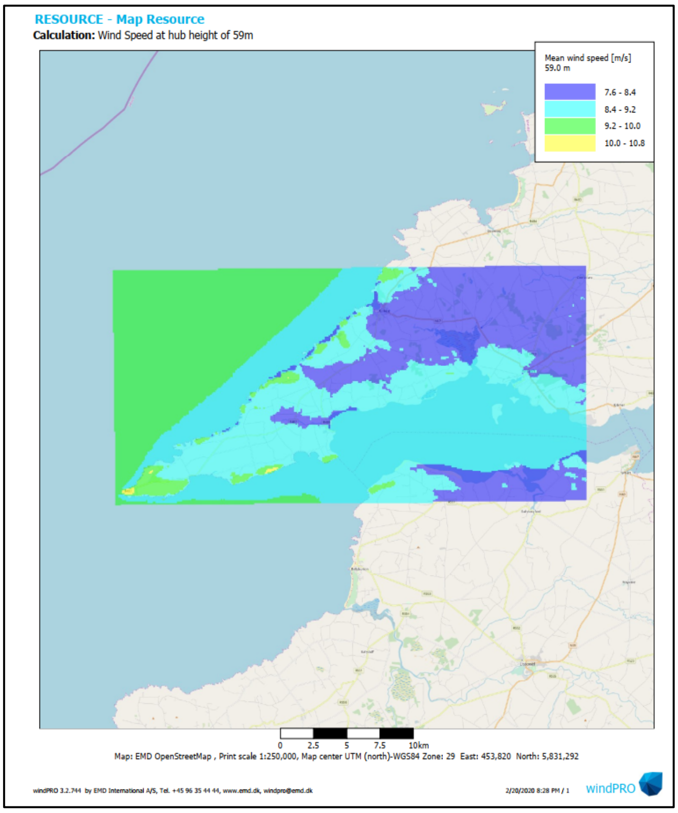


Figure 5-5 Wind Speed (m/s) at the hub height of 59m in Loop Head (Source: Author's calculation using WindPro, Map Source: (EMD))

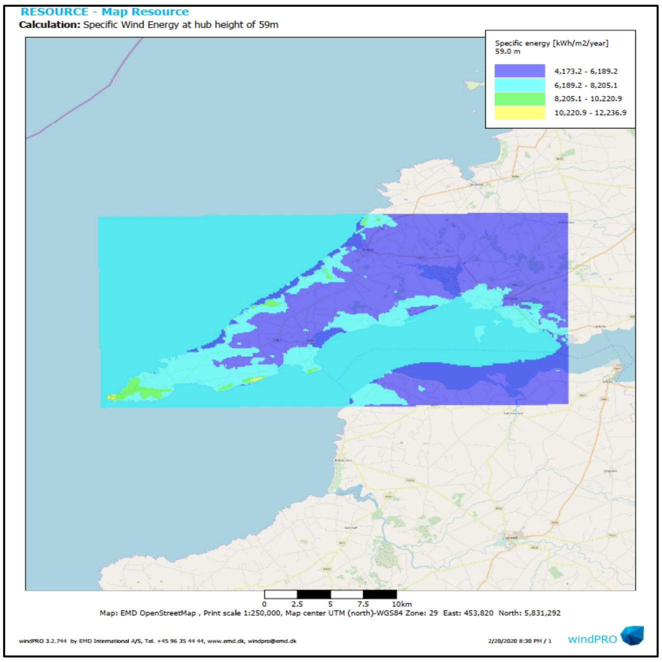


Figure 5-6 : Specific energy generation (kWh/m2/year) in Loop Head (Source: Author's calculation using WindPro, Map Source: (EMD))

Annual Energy Generation from Existing Wind Farm

2 Enercon turbines of 2.3 MW are operating in wind farm (W1= 52.635176º, -9.723783º and W2= 52.632556º, -9.723173º) at the hub height of 59m in Loop Head as shown in Figure 5-7. The power curve of ENERCON E70, 2.3 MW turbine has been attached in Appendix 10. showing the cut-in speed of 2 m/s, rated speed of 15 m/s and cut-out speed of 25 m/s for power production.

Figure 5-7 Map showing two existing wind farms in Loop Head

(Map Source: (Google, 2019))

The annual energy generation from these two turbines after simulating correlated data of the year 2018 is 13.82 GWh considering 10% of safety margin. Figure 5-8 shows the annual energy generation from the existing turbine without any losses.

PARK - Reference WTGs

Calculation: Park with 29 years MCP

Setup
AEP assuming long term representative time series data with optional corrections

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: -0.6°

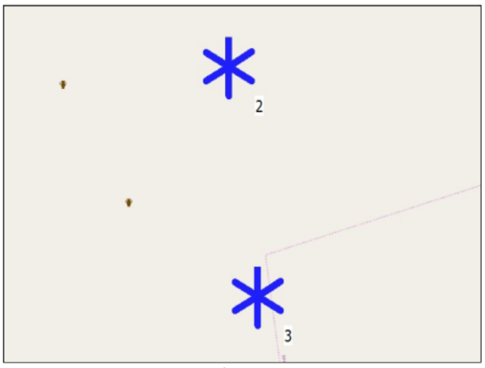
Wake
Wake Model: N.O. Jensen (RISØ/EMD)
Wake decay constant
Wake decay constant: 0.075 DTU default onshore

Scaler/wind data

Name	EMD Default Measurement Mast Scaler
Used period	1/1/1990 - 11/30/2019 11:00:00 PM
Meteo object(s)	Default Meteo data description (24) (Regression MCP using ERA5_N52.693186_W009.450000 (25)), 100.00m -
Displacement height: Omnidirectional from objects	
WAsP version	WAsP 11 Version 11.06.0012

Power correction (All existing WTGs)
Power curve correction (adjusted IEC method, improved to match turbine control)

		Min	Max	Avg	Corr. [%]	Neg. corr. [%]	Pos. corr. [%]
Air density							
From air density settings	[°C]	9.5	9.6	9.6			
From air density settings	[hPa]	1002.1	1002.9	1002.5			
Resulting air density	[kg/m³]	1.235	1.236	1.235			
Relative to 15°C at sea level	[%]	100.8	100.9	100.8	0.6	0.0	0.6



Scale 1:7,500
New WTG   Existing WTG

Calculated Annual Energy for reference WTGs

			Specific results	Specific results		Wind speed			
Calculated prod. without new WTGs	GROSS (no loss) Free WTGs	Wake loss	Capacity factor	Mean WTG result	Full load hours	free	wake reduced	Actual wind corrected energy	Goodness Factor
[MWh/y]	[MWh/y]	[%]	[%]	[MWh/y]	[Hours/year]	[m/s]	[m/s]	[MWh/y]	[%]
15,359.0	15,611.2	2.3	38.1	7,679.5	3,339	8.5	8.4	0.0	

Calculated Annual Energy for each of 2 reference WTGs with total 4.6 MW rated power

	WTG type						Power curve			
	Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Creator	Name	Calculated prod. without new WTGs	Goodness Factor
				[kW]	[m]	[m]			[MWh/y]	[%]
2	Yes	ENERCON	E-70 E4 2,3 MW-2,300	2,300	71.0	59.0	EMD	Level 0 - guaranteed* - OM II/Rev 1.0 - 05/2005	7,567.7	0
3	Yes	ENERCON	E-70 E4 2,3 MW-2,300	2,300	71.0	59.0	EMD	Level 0 - guaranteed* - OM II/Rev 1.0 - 05/2005	7,791.3	0

WTG siting

	UTM (north)-WGS84 Zone: 29						Calculation period	
	Easting	Northing	Z	Row data/Description	Production source	Statistical basis for normalized production: [Months]	Start	End
			[m]					
2	451,019	5,831,934	25.8	ENERCON E-70 E4 2,3 MW 2300 71.0 !O! hub: 59.0 m (TOT: 94.5 m) (11)			1/1/1990	11/30/2019
3	451,057	5,831,642	32.6	ENERCON E-70 E4 2,3 MW 2300 71.0 !O! hub: 59.0 m (TOT: 94.5 m) (12)			1/1/1990	11/30/2019

Figure 5-8: Annual energy production from existing wind farm in Loop Head without considering 10% uncertainty (Source: Author's calculation using WindPro, Data Source: (EMD)

5.3 Biomass

The objective of the following analysis is to understand the total amount of biomass resources in the region, which can be used to calculate the renewable energy potential from biomass in Loop Head. The analysis was done based on a detailed assessment of the data in the Census of Agriculture 2010 by the Central Statistics Office (CSO), the Census of population, the Forest Service inventories, a field research in the area with farmers and interviews with different stakeholders. The analysis is focused mainly on three types of resources present in the study area: Agricultural feedstocks, household and commercial organic waste and forestry crops.

The methodology to calculate the energy resources is based on the potential generation of biogas for agricultural feedstocks and organic waste. In the case of forestry, the energy content is calculated based on the annual average production in the study area. More details about the methodology and calculations are addressed in the Appendix 4.

Figure 5-9 summarizes the total amount of energy from biomass resources in the Loop Head peninsula according to the source and type. It is important to mention that most of the silage is already being used to feed livestock.

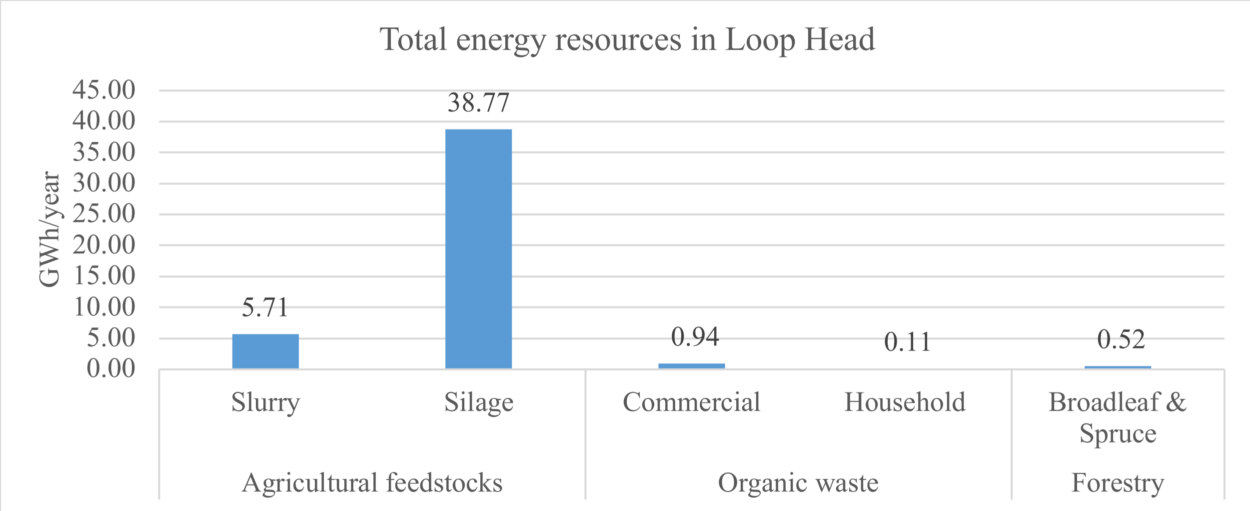


Figure 5-9 Total energy in biomass resources based in own calculations.

5.3.1 Agricultural feedstocks

Agricultural feedstocks represent most of the biomass resources in the area. Crops, mainly silage, pastures and rough grazing represent 86.7% of the area cultivated. The livestock count was 17,601 were approximately 59.5% is used for meat production and 40.5% is used in diary activities (Central Statistics Office, 2010).

Two agricultural feedstocks have been considered in the biomass resource assessment; (i) Manure slurry from cattle and cows: a mixture of animal waste, organic matter, used as fertilizer and stored mainly during the winter season from November to May and (ii) Grass silage: preserved pasture used to feed livestock mainly during winter season.

Manure slurry from other livestock such as sheep, ewes or rams is not considered since they represent only 1.9% of the livestock count in the region (Central Statistics Office, 2010).

Resource mapping was done based on the technical and practical calculations. The main objective is to facilitate visualization of the resource allocation in Loop Head.

Initially, cattle distribution was mapped based on the 2010 census data (Central Statistics Office, 2010). Based on the data, the total cattle in Loop head is estimated to be 17,601 with most of the cattle near Kilbaha with a total count of 4,018 heads followed by Carrigaholt with a total cattle count of 2,753.

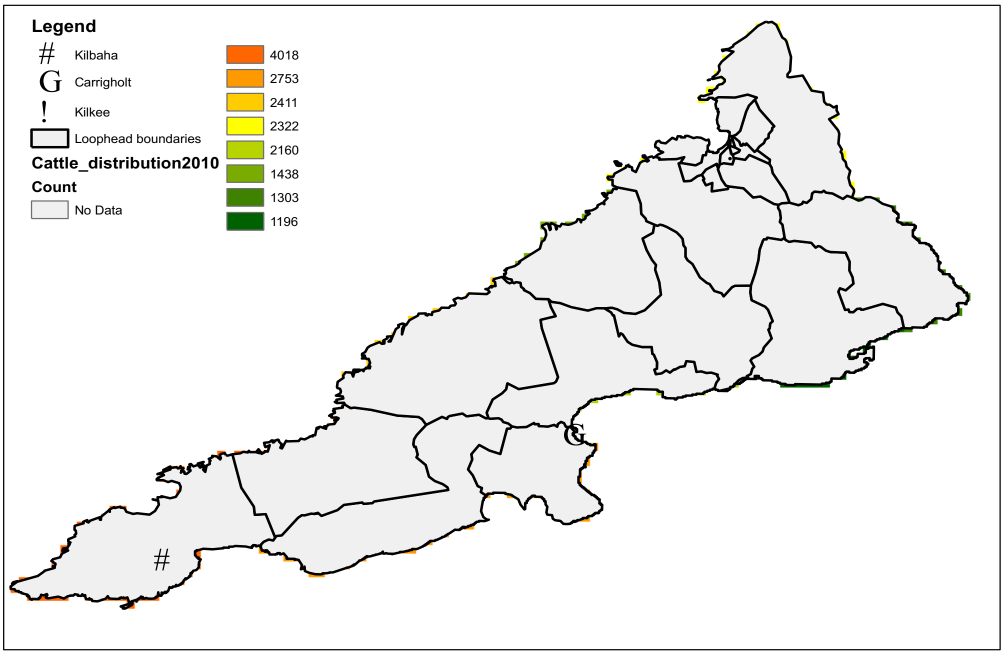


Figure 5-10: Cattle distribution based on Census (Data Source: (CSO.ie, 2019), simulated using ARCGIS)

5.3.2 Organic waste

Organic waste represents a 2% of the energy in the biomass resources in the area. The main share of the organic waste is produced in the commercial sector. Based on data gathered from interviews, an estimation of 1,899 tons per year of food waste is produced by hotels and restaurants mainly located in Kilkee. In the case of households, the potential was calculated based on the average organic waste production of 84.5kg/person in Ireland (Amlinger, Favoino, Prasad, & Foster, 2010) and the total population of 2,567 (CSO, 2016) in the area. The organic waste is collected centrally by the company Clean Ireland Recycling where it is processed in an anaerobic digester.

5.3.3 Forestry

Forestry production represents 1.1% of the total energy potential of biomass in the study area. Broadleaf and spruce are the main species produced and used mainly as firewood. According to the forest cover map of the Irish Forest Service all the forest developments in the area are under private ownership.

Table 5-1 presents the production until 2035 (Department of Agriculture, Food and Marine, 2017). Considering an average production of 377.1 m^3 the total energy produced from forestry is equivalent to 0.52 GWh/year.

Table 5-1: Forestry planned production 2016 – 2035 Source: (Department of Agriculture, Food and Marine, 2017)

Planned production (m^3)	2016-2020	2021-2025	2026 - 2030	2031 - 2035
Broadleaf	5	5	5	2,126
Another Conifer	5	5	5	5
Spruce	637	947	3,596	201

5.4 Biomass practical potential in Loop Head Peninsula

The analysis of the biomass resources indicates that agricultural feedstocks have a significant potential in the area that can be considered for further development. Food waste has been discarded as a practical potential since this resource is small and already tapped. Forestry can be considered in future scenarios; studies in Northern Ireland have shown that the production of biomass from marginal willow for direct combustion gives an energy output of 37.7 MWh/ha/year (McElroy & Dawson, 1986). According to the resources present in the areas slurry and silage can be used to produce biogas. Nine interviews were held with farmers dedicated to cattle and dairy operations in order to assess the practical potential of an anaerobic digestion (AD) plant. Table 5-2 presents the information collected from interviews.

Table 5-2: Collected information from the interviews (Source: field interviews, February 2020).

	Min	Average	Max
Land currently used for agriculture (ha)	17	56.14	141.6
Land available for agriculture (ha)	23	65.1	161.8
Productivity of land under silage (bales/acre)	5	9	12
Livestock count (number)	25	116.4	320
Total slurry storage capacity (m^3)	28	190.0	473.1

5.4.1 Silage as feedstock for biogas

Results indicate that farmers can increase the total silage production by 15.93 %. With present production techniques, an equivalent of 4,679 tons of silage per year can be produced on agricultural land that, which is currently not used. This silage can be used for energy production without changing the present production model. This resource represents 1,029 thousand cubic meters of biogas, with a total energy content equivalent to 6.18 GWh per year. This feedstock will be only considered in one of the scenarios that aims at maximizing the biogas production and upgrade it to biomethane in the further chapters. The remaining silage is not considered in the potential calculations since is already used as livestock feed.

5.4.2 Slurry manure as feedstock for biogas

A workshop was conducted with local farmers to verify the figures on cattle population. The result of this workshop is shown in the Figure 5-11. It is largely in line with the geographical distribution derived from the 2010 census. Most of the farms are located near Kilbaha and Carrigaholt, thus more cattle is distributed around these towns than in the areas around Kilkee. It needs to be mentioned that the farm located near Kilkee with a cattle count of 800 is a group of three farms combined. However, this was pointed on the map by the farmers as one location with total cattle and mapped accordingly. A total cattle amount of 14,130 will be considered as the basis of the practical potential calculation. These farm locations and livestock numbers were then used for the selection of the AD plant location as will be illustrated in chapter 8 of this report. Based on the above-mentioned calculations for the practical potential, the slurry in the area was estimated to be around 66,249 tonnes per year. Considering 10% losses in the collection process and transportation this amount of slurry represents 952 thousand cubic meters of biogas, with a total energy content equivalent to 5.71 GWh per year.

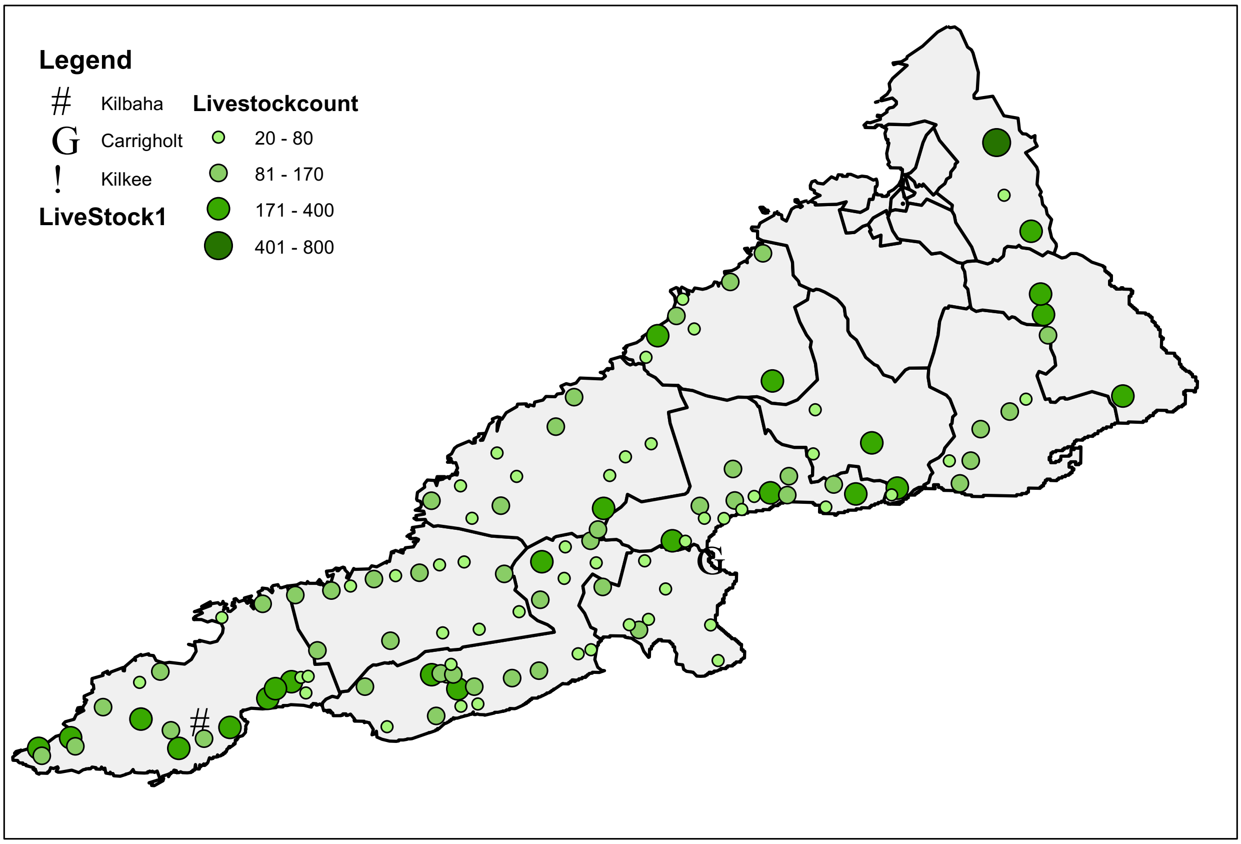


Figure 5-11: Livestock distribution as estimated by local farmers (Data Source: Farmers workshop dated February 6th 2020, visualised using ArcGIS)

5.4.3 Practical potential to produce biogas

The analysis indicates that the production of biogas in Loop Head peninsula depends on the mix of feedstock used. Considering slurry manure and silage a total of 11.9 GWh/year can be produced equivalent to 1,981 thousand cubic meters of biogas. Compared with the total resources of biomass it can be concluded that 25.8% of the resources present in the area can be used to produce energy.

5.5 Wave

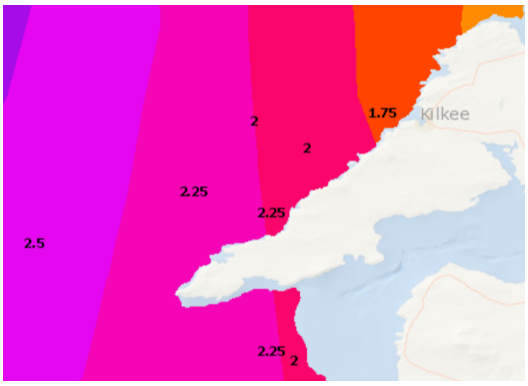
In this section, the estimated potential for wave energy in the Loop Head peninsula is presented considering the theoretical resource (hydrodynamic energy contained in waves) and the technical resource (Electricity produced from a real wave energy converter (Marine Institute Sustainable Energy Ireland, 2005).

5.5.1 Theoretical wave energy resource

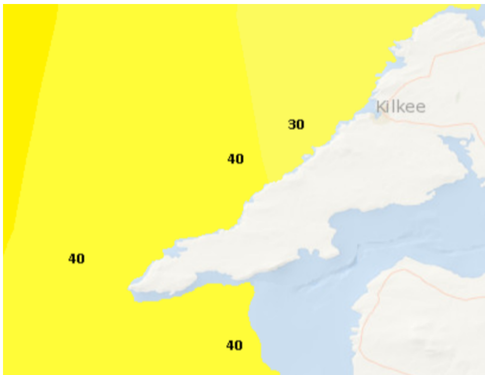
The mechanical energy of a wave is directly proportional to the height and period of it (Alcorn, 2014). Figure 5-12.a illustrates the mean annual distribution of wave height in the different coasts of the Loop Head Peninsula. It can be seen that the height tends to increase to the south west of the peninsula and tends to decrease towards Kilkee coast. In average, the height of the waves is approximately 2 meters in the coast of the peninsula.

Figure 5-12.b shows the mean annual theoretical wave power flux in the Loop Head Peninsula. It can be seen that this parameter is higher in those areas where the waves are higher.

Therefore, it can be speculated that higher power will be obtained to the southwest coast of the Loop head peninsula. In average, power fluxes between 40-30 kW/m of wave length are found in Loop Head.



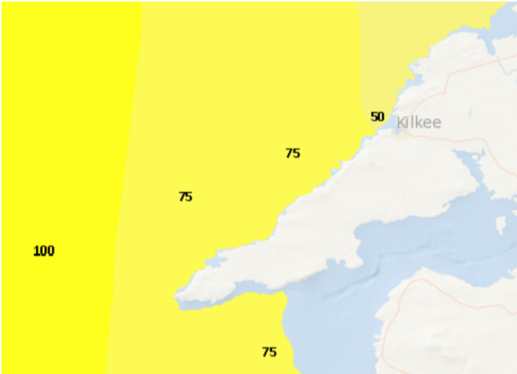
(a)



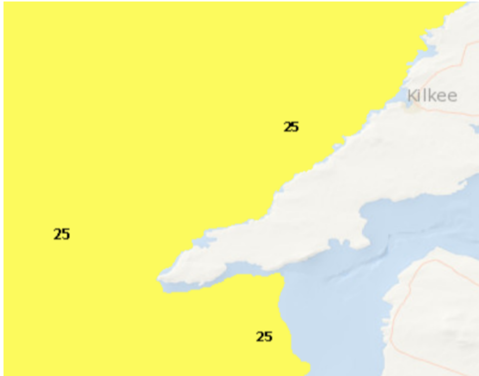
(b)

Figure 5-12: a) Mean annual distribution of wave height in the Loop Head Peninsula. Unit: meter b) Mean annual theoretical wave power flux in the Loop Head Peninsula. Unit: kW/m of wave length. Source: (Marine Institute, 2016)

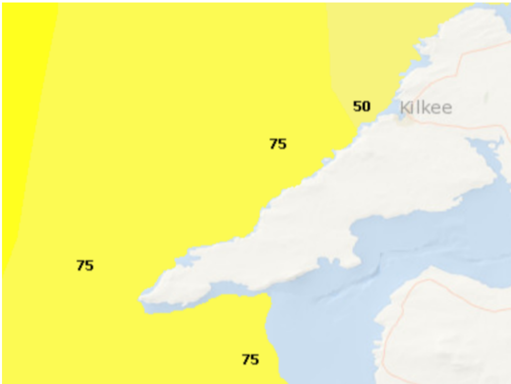
The hourly power density values of the year are summed to give place to the annual theoretical wave energy resource in MWh/m (Marine Institute Sustainable Energy Ireland, 2005) .The Figure 5-13 illustrates the seasonal distribution of the wave energy theoretical resource in Loop Head Peninsula. The unit is MWh/m (theoretical energy that could be harnessed per meter of crest width) (Marine Institute Sustainable Energy Ireland, 2005). It can be seen that in winter the energy resource is the highest, while in summer it tends to reach the lowest levels. In addition, the resource tends to be higher to the south west coast of the peninsula and lower towards Kilkee coast.



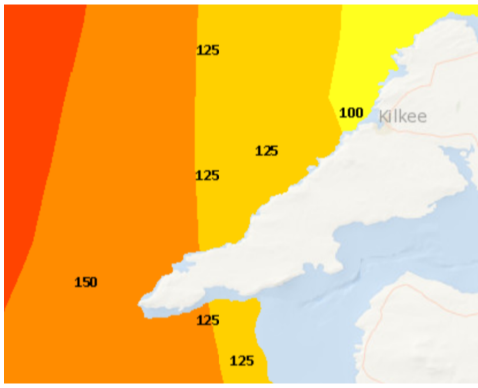
(a)



(b)



(c)



(d)

Figure 5-13: Seasonal distribution of the wave energy theoretical resource in Loop Head. a) Theoretical resource in Spring b) Theoretical resource in summer c) Theoretical resource in Autumn d) Theoretical resource in winter. Source: Ireland´s Marine Renewable Energy Atlas.

5.5.2 Technical wave energy resource

To evaluate the technical potential, a real wave energy converter is considered, in this case the Pelamis converter which was used in the world´s first commercial wave energy project in Portugal in 2008 with capacity of 2.25 MW (Power Technology). The capacity of a string of this converter is 14.25 MW/km (Marine Institute Sustainable Energy Ireland, 2005). A Pelamis converter is shown in Figure 5-14.

Figure 5-14 : Pelamis wave energy converter. Source: (BBC, 2018)

In addition, the following situations have to be avoided to have a proper functioning of the energy converter:

- Areas with depth lower than 50 m
- Areas at over falls and wrecks
- Areas further than 100 km from coast
- Areas where surface currents exceed 1 knot

According to Figure 5-15, water depths higher than 50m can be found from approximately 5 km away from the coastline of the peninsula. This suggests that energy converters might be feasible located at least 5 km off the coastline.

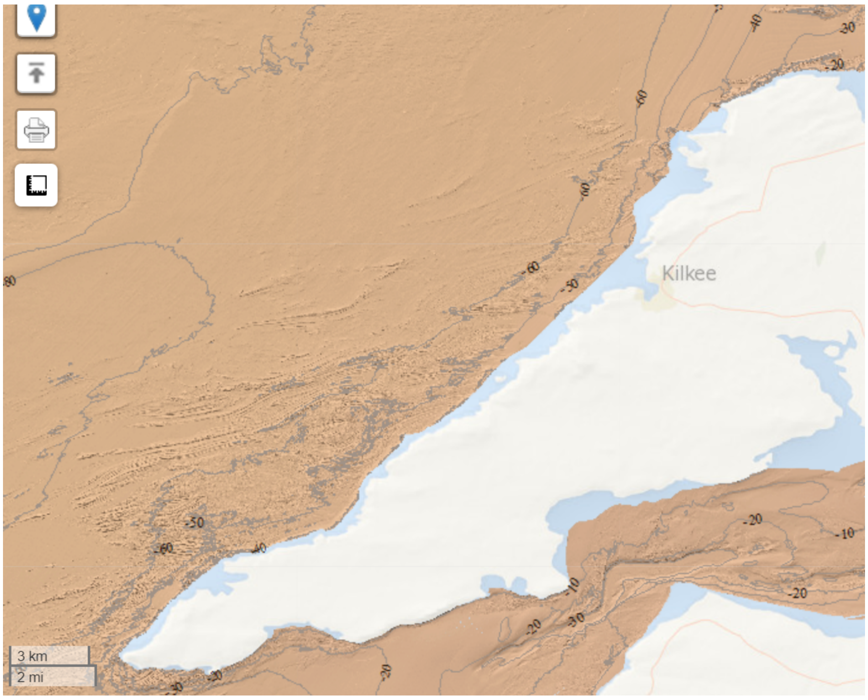


Figure 5-15: Water depths in Ireland. Unit: meter. Source: (INFOMAR: Marine institute and Geological Survey of Ireland)

The Figure 5-16 shows the mean annual technical wave energy potential off the coast of the Loop Head Peninsula in GWh of electricity per km. It can be seen that the farther from the coast the higher the potential. The Figure 5-16 also shows that if the Pelamis converter is located between 20-30 km away from the coast it might generate 30 – 34 GWh/year, between 10 -20 km it would generate 26 -30 GWh/year and within 10 km away the coastline it might produce 16 – 26 GWh/year.

According to the Marine Institute, installing a 1 km string Pelamis energy converter 30 - 40 km away from the coastline of the Loop Head Peninsula would generate approximately 34 GWh/year of electricity on average (Marine Institute Sustainable Energy Ireland, 2005). The estimated electricity demand in Loop Head considering the total demand of hotels, buildings, water world, farming sector, 100% of electric cars and 20% of residences equipped with heat pumps, is about 22.45 GWh/year. In this sense a Pelamis converter located 30-40 km away the coastline of Loop Head might generate the equivalent to 1.53 times the electricity demand in the Peninsula.

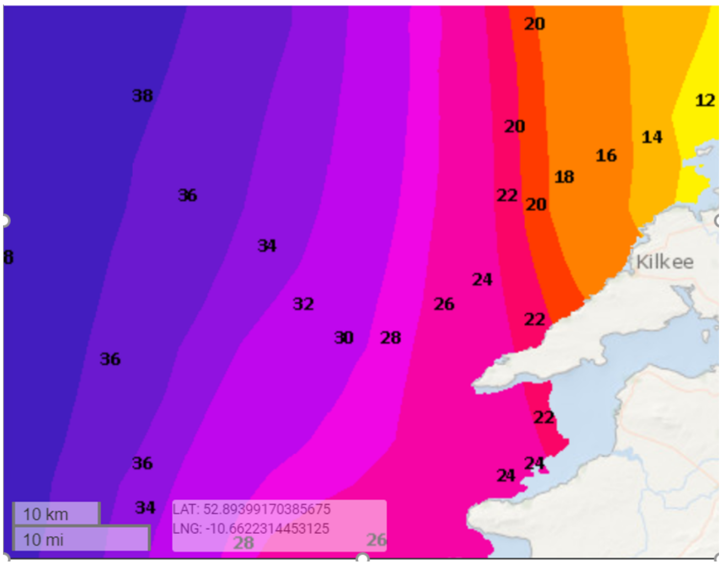


Figure 5-16: Annual technical wave energy potential. Unit: GWh/km. Source: (Marine Institute, 2016)

5.5.3 Current state and cost of wave energy technology

Wave energy resource has a big potential for electricity generation in many regions of the world. However, the commercial utilization of this technology is currently very low since it is a technology still under study compared to wind and solar. At the time being, theoretical studies, testing of wave energy converters prototypes, computing modelling to represent wave energy variability, numerical simulation, etc., have been done in order to optimize the energy capture by the wave energy converters. Studies on the best placement of wave converters at large scale has yet to be performed (Aderinto, 2018).

In general, 11.3 MW of wave energy has been installed in Europe since the year 2010. It is stated that 2.9 MW of this number is currently in the water and 8.4 MW was for pilot projects which have been already decommissioned. Scandinavia and Italy are taking the lead in wave energy in Europe (Ocean Energy Europe, 2018).

According to the European Commission the LCOE for Wave to Energy technology was about 560 Euros/MWh in 2018 (for comparison 50.32 EUR/MWh for onshore-wind and 76.32 Euros/MWh for utility scale solar PV projects (IRENA, 2019)) given a CAPEX of 6970 kEuros/MW and capacity factor of 25%. It is projected that the CAPEX for wave technology reaches 3,350 kEuros/MW by 2025 and 2,000 kEuros/MW by 2050 if wave energy enters the market competitively (European Commision / Low Carbon Energy Observatory, 2019).

In accordance with SEAI the use of the wave energy potential depends largely on how cost-effective is the technology selected, the amount of power than can be connected to the electricity network, social acceptance, possible environmental impacts and interaction with other users of the marine resource.

Currently, Ireland is developing a 5 MW wave energy project in Doonbed, County Clare which is sponsored by ESB (ESB, 2020).

6 Vision

The total energy demand of Loop Head is majorly met by fuels that are imported from outside of the region. This import costs € 7.3 Million including electricity, diesel, coal, oil, and LPG to meet electricity, heat and transport demand. The vision is to make Loop Head self-sufficient in energy so that money going out of Loop Head for energy import bills can be kept in the area. This money can be used for the welfare of the community in Loop Head. If a larger degree of energy self-sufficiency is achieved using energy efficiency and renewable resources, this can help to reduce the environmental impacts of fossil fuel consumption and create income for the community from energy projects. This can also create jobs in Loop head. There can be business opportunities for people retrofitting buildings, installing photovoltaic systems, heat pumps and other energy efficient heating technologies. Plumbers and electricians will be required for the maintenance of these systems. These measures can also make Loop head a more sustainable place and it will help in attracting tourists who find sustainability important.

Residential Buildings

Residential buildings and B&Bs can save 50% of the heat demand with improved insulation and still save money, even when the investment is accounted for. It will reduce their heat demand by almost 9000 MWh and will help in avoiding 2,500 tons of CO_2 going into the environment. This reduction in heat demand reduces the fossil fuel demand by around 11,000MWh saving almost 700,000 Euro annually. Similarly, a 3kW solar PV system on 50% of the houses can generate around 1,500 MWh of electricity. This would cover 34% of the electricity demand of individual households. Excess electricity can be used to meet part of the water heating demand of 575MWh.

If 20% of the energy-efficient houses are equipped with heat pumps, this would replace 4,160 MWh of fossil fuels, saving 269,000 Euro annually. 627 tons of CO_2 are also avoided by replacing fossil fuels for heating.

Hotels

Hotels are using LPG and electricity for their heat demand. Each hotel can install a 40kW solar PV rooftop system to generate a total of 190 MWh of electricity to meet their electricity demand. Heat pumps can be installed to meet the heat demand of 715 MWh annually. This will save around 115,000 Euros in terms of heating bills in addition to CO2 savings.

District Heating system fed by Biogas boiler

A small district heating system in Kilkee fed by a biogas boiler can supply a number of hotels, residential buildings, other commercial premises and the swimming pool in Kilkee and replace around 1,500 MWh of fossil fuel as well as 800 MWh electricity.

Community-owned Energy Projects

Assuming specific investment cost as in the UK a small solar farm of 5MWp capacity developed as a community-owned energy project can generate 5.0 GWh annually. Similarly, a community-based wind turbine of 2.3 MW capacity can generate 6.6GWh/annum with an average annual benefit of 485,000 Euros to the community. The revenues generated from community-owned power projects could be utilized to implement projects that benefit the community, for example a public transport system based on electricity.

Public Transport

Implementation of public transport can be useful for local community as well as tourists. Currently, 2700 passenger trips which can be increased if tourists use the public transport. If an electric minibus is started as public transport, it will have lower fare as compared to diesel bus. If there is a demand of 6000 passengers per year, the fare for diesel bus will be 5.5 Euros whereas for electric bus it will be around 4.5 Euros.

Once all these measures are taken, the final energy system will look like below:

Table 6-1 Insight to Future

	Before	After	Before	After
Saving heating fuels by energy retrofits, installation of heat pumps and solar PV roof top systems in the residential sector	31300	15851	2,033,600	1,348,000
Saving heating fuels by installation of heat pumps and solar PV roof top systems in Hotels and B&B	31300	30560	2,454,800	2,396,800
Saving electricity imports by installation of solar PV roof top systems in the residential sector, Hotels and B&B	21,715	10,850	4,987,900	2,492,200
Saving heating fuels by a district heating system based on an anaerobic digester	-	1,250	-	100,000
Saving Diesel by implementing a public transport system based on locally produced renewable electricity	-	78	-	10,000
Saving Diesel by implementing a EV on locally produced renewable electricity	-	7,120	-	926,000

All the above-mentioned alternatives are explained in the coming sections of pre-feasibility studies including their cost and benefit. These alternatives could help in achieving a bigger vision of the self-sustainability for energy and generating jobs which will lead to increase income and welfare of the community. The same can be simulated using the model prepared in conjunction to this report

7 Policies and Regulation

7.1 Farming Sector

Policies and regulations drive renewable energy technology implementation in the agriculture sector. According to (Agriland, 2020), ‘‘a total of 6 GW of farm solar PV (30,000 acres) is proposed to be developed across the country and mainly in the east and south of Ireland”. Based on the assumption that there is better grid access. The highlighted potential depends on many variables including access to the grid, grid cost, planning permission, building cost as well as location scale which is highly dependent on regulations. Solar PV systems on farms are highly commendable as they can be installed on a current structure on the farm, major savings could be achieved by investing in a PV system on a farm stipulated under the Renewable Energy Farm Grant scheme (Enerpower, 2020).

7.1.1 Targeted Agricultural Modernisation Schemes

A Renewable energy farm grant is available under the Targeted Agricultural Modernisation Schemes (TAMS) system. This new scheme has €10m worth of grants available for energy efficiencies and renewable energy technologies (Enerpower, 2020). Moreover, TAMS Support offers a standard of 40% on investment up to a ceiling of €80,000 for a solar PV system (Caslin, 2016). The Minister for Agriculture, Food and the Marine, Michael Creed T.D, stated that “the grants where part of the wider drive to position Irish agriculture as a global leader in sustainability” (Enerpower, 2020). Moreover, the ability to generate electricity as a prosumer. A prosumer is a consumer who becomes involved with designing or customizing products for their own energy needs. The grants expect to attract more people to become a prosumer, a consumer that can designing or customizing products for their own energy needs. Generating one’s own electricity is going to be valuable and important as planned Government increases in carbon taxes start to bite (Agriland, 2020). The scheme, which is under the Department of Agriculture food and Marine, also entails low emission slurry spreading equipment scheme aimed at supporting and assisting farmers to purchase new equipment for the spreading of slurry which has distinct environmental advantages (Ministry of Agriculture, 2019).

7.1.2 Planning Permission

In terms of regulation, planning permission on agriculture structures or within the curtilage of an agricultural holding require that ground mounted solar PV array shall not exceed 25 m^2 with a height of the free standing solar array not exceeding 2 metres (Caslin, 2016). A roof mounted PV system not exceed 50 m^2 or 50% of the total roof area whichever is the lesser is exempted from planning permission. The solar panels on farm roof tops shall be a minimum of 50 cm from the edge of the wall or roof on which it is mounted. Moreover, a farmer can install a larger PV system on his farm, in the event that a planning permission is granted. According to (Agriland, 2020) For every 10 kWp of solar PV installed on a farm approximately 5 tonnes of carbon will be displaced per year, thus a solar PV system could be a sustainable initiative on farms.

7.1.3 Grid Connection

No Prior permission is needed to connect to the electricity distribution network operator ESB for a system up to 16A (Amps) per phase that is 3.68 kW single phase and 11.04 kW three phase. However, a larger system over 26A/16A requires prior permission to feed into the grid. ESB operates an “inform and fit” policy, where one fills in a NC6 form. This gives guidance to the commissioning of the system which must comply with EN50438 standard (Caslin, 2016). The Republic of Ireland does not have any Feed in Tariff for solar PV at present (Caslin, 2016). Thus, connecting to the grid might not be economically feasible.

7.1.4 Value added Tax Claim

A farmer can claim back the VAT incurred on the purchase of a solar PV system which is designed to be used solely on his or her farming business. The VAT flat rate return stipulates that the PV system must be named on Triple E product register maintained by the Sustainable Energy Authority of Ireland (SEAI) which complies with the energy efficiency criteria of that authority (Caslin, 2016).

7.2 Residential Sector

7.2.1 Warmer homes scheme

The main goal of this grant is to support local households to solve their heating issues (fuel-poor families[10]). Over 135,000 families already received funding under warmer homes scheme and improved their home conditions. There is a list of households who are eligible to apply for this funding: people that are receiving job seekers allowance for over 6 months and have a child under 7 years of age; one-parent families; families that are receiving care allowance, fuel allowance, domiciliary care allowance. One additional requirement - the homes must be built and occupied before 2006. An improvement of these households is provided for free. The following is included in this scheme: the insulation of attic, wall or installation of ventilation can be provided, the installation of efficient lighting, heating boilers. The waiting period is up to 18 months after application (SEAI, 2017).

7.2.2 Better energy homes scheme

The scheme provides grants for households to improve the energy efficiency of their homes. Main requirements for this grant are that the house must be built before 2006 for insulation and heating control systems, for heat pumps and solar thermal grants the house can be built before 2011. There are 1,027 houses which are built before 2006 in Loop Head, taking into account the fact that 20% of homeowners already applied and received this grant (assumption based on conducted surveys), potentially 822 households can apply for insulation and heating control systems grant for the first time and the rest of houses can reapply to get additional home improvements. Almost all houses in Loop Head can apply for heat pumps and solar thermal grants. It should be mentioned that grants are paid after the work has been completed. The level of upgrade that can be done in the framework of this project: attic and wall insulation; heat

[10] Households that spend more than 10% of their income on energy. (SEAI, 2017)

pump system installation (air to water, ground source to water, exhaust air to water, water to water, air to air); heating control upgrade (thermostatic radiator valves, 7-day programmable timer, boiler interlock, time and temperature control of electric immersion heater); solar water heating installation. A more detailed description of the funding and application procedure is available here (SEAI, 2019). After the home improvements completed and a grant is received the owners should undertake a Building Energy Rating (BER) on their home.

7.2.3 Supporting scheme for heat pumps system

Grants are provided to install a heat pump system in an already well-insulated home. Based on data provided from (CENSUS Statistics, 2016) and (SEAI_d, 2017) the average number of households in Loop Head that can already apply for this grant is 35. Heat pumps are more efficient compared to other conventional technologies. Before applying for a heat pump system grant, homeowners should contact an independent, SEAI Registered Technical Advisor. They will evaluate the possibility of heat pump installation in the house and provide technical guidance for installing a heat pump. There is a grant available for technical assistance of the house at the level of 200 Euro. The total amount of grants for such heat pumps as air-to-water, ground source to water, exhaust air to water, water to water is 3,500 Euro and for air to an air heat pump is 600 Euro (SEAI, 2017).

7.2.4 A microgeneration Scheme supporting the upscale of household solar PV

Before 2019 all homeowners of occupied buildings built before 2011 had a chance to get the support from SEAI to install rooftop solar PV According to the results of previous supporting scheme 1,500 households installed solar PV system with an installed capacity of 5 kW each, a number of registered PV installers also increased during this SEAI program to 100 companies. Under a new rule adopted in December 2019, the application for new household solar PV scheme is available for houses which have BER C or better (SEAI_c, 2019). Based on the data of households that have BER, there are 173 households in Loop Head who are eligible to apply for this program (SEAI_d, 2017). The main goal of the updated supporting scheme is to encourage the homeowner to self-consume electricity generated by solar PV. If before the grant covered 700 Euro for every kWp up to maximum 4kWp, under a new supporting scheme for the solar PV system up to 2 kWp the grant is 900 Euro per kWp and for solar PV system 2-4 kWp the grant is 300 Euro per kWp. In case the estimated solar PV panels system is over 2kWp, it can be installed in combination with batteries for which a 600 Euro grant is available. Before the installation of the PV system, the homeowners should apply for ESB Networks (SEAI, 2017). If homeowner decided to cover less than 50 % of the roof the official permission is not required, otherwise larger solar PV systems on domestic rooftops will require planning permission (SEAI_d, 2019).

7.3 Community owned Energy Projects

7.3.1 Renewable generation support schemes

Until December 2015, renewable electricity support schemes existed in Ireland under REFIT 1, 2 and 3 (DCCAE, 2020). Even though, the current generation capacity from RE amounts to 3,500 MW (Goverment of Ireland , 2020), yet the share of this capacity owned by a community is estimated to be only 0.13%. This share is owned solely by Templederry Wind Farm (TipperaryEnergyAgency) being the only existing community group to generate and sell renewable electricity to the grid in Ireland (DCCAE, 2019). This reflects the absence of policies and supports for the renewable electricity generation for communities.

Since the closure of the REFIT scheme in 2015, there is currently no active support scheme for renewable generation in Ireland. However, currently a new scheme is proposed, "Renewable Electricity Support Scheme (RESS)" (DCCAE, 2020). The RESS is set to achieve Ireland's contribution to the EU target of renewable energy share of 32% by 2030 (Goverment of Ireland , 2020). In addition, the RESS is designed to enable community participation in RE projects and to increase renewable technology diversity (Goverment of Ireland , 2020). The new RESS is designed to support technologies which were not supported under the REFIT scheme such as solar PV and off-shore wind (Goverment of Ireland , 2020). This is planned by placing a technology cap during the auctions and 3 years viability gap analysis prior each auction; which means that technologies no longer requiring subsidies will not be qualified to participate in the auctions (Goverment of Ireland , 2020).

The first auction under RESS was planned in 2019 (Goverment of Ireland , 2020), with the auction capacities as shown in the below table. This date was not achieved and the proposed new date for RESS-1 is in June 2020 (DCCAE, 2019). However, it's still not clear whether this new date is going to be achieved.

Table 7-1: RESS auction overview Data source: (Goverment of Ireland , 2020)

<table>
<tr><th></th><th>Auction Capacity (GWh)</th><th>Auction Year</th><th>Delivery Year (end of)</th><th>Technology CAP</th></tr>
<tr><td>RESS-1</td><td>1,000</td><td>2019</td><td>2020</td><td>No</td></tr>
<tr><td>RESS-2</td><td>3,000</td><td>2020</td><td>2022</td><td>Yes</td></tr>
<tr><td>RESS-3</td><td>3,000</td><td>2021</td><td>2025</td><td>To be considered</td></tr>
<tr><td>RESS-4</td><td>4,000</td><td>2023</td><td>2027</td><td>To be considered</td></tr>
<tr><td>RESS-5</td><td>2,500</td><td>2025</td><td>2030</td><td>To be considered</td></tr>
<tr><th colspan="5">The volume capacity required per technology to deliver a sample of 1000 GW</th></tr>
<tr><th colspan="2">Technology</th><th>Capacity Factor</th><th colspan="2">Capacity in MW</th></tr>
<tr><td colspan="2">On-shore wind</td><td>31%</td><td colspan="2">356</td></tr>
<tr><td colspan="2">Off-shore wind</td><td>45%</td><td colspan="2">253</td></tr>
<tr><td colspan="2">Solar PV</td><td>11%</td><td colspan="2">1000</td></tr>
<tr><td colspan="2">Biomass</td><td>85%</td><td colspan="2">134</td></tr>
</table>

In order to increase community participation and ownership under RESS, different policies and support mechanisms are proposed to support community-led projects including financial support in the form of grants covering feasibility studies and capacity building during the early phases of the project (Goverment of Ireland , 2020). The grants for the feasibility studies will not be reclaimed in case the projects don't go forward (Goverment of Ireland , 2020). This is a positive approach, as it reduces the financial risk for the interested communities' groups during the early stages of the projects.

The share of community owned projects will vary from 5% to 15%, which will be determined for each auction after RESS-1 (Goverment of Ireland , 2020). Based on the above table, it could be estimated that the minimum share under RESS-2 for community led projects may be around 150 GWh while the maximum may be 450 GWh. This roughly translates to an equivalent of 17MW to 50 MW capacity. Since under RESS scheme, a community led project capacity is limited to 5MW (DCCAE, 2019), this translates to an estimate number of projects ranging from 3 to 10 for communities under RESS-2. It's not clear if this share will be encouraging to the communities to participate, however it may result in a very high competition among the projects participating since the number of projects to be awarded are limited. However given the time needed for the communities to get organized to be eligible to apply for the auction; as they require prior participation to have a full planning permission and a grid connection offer (Goverment of Ireland , 2020); there is a high probability that many projects will not be awarded under this small share, which may lead to discouragement among the communities. The details of how the community should be organized under RESS are illustrated in chapter 8 of this report.

Two basic pricing approaches are proposed under RESS: uniform price approach or floating feeding premium (Goverment of Ireland , 2020) . Under uniform price, the clearing price to meet the required capacity will be set by the highest bidder and all offers below the clearing price will receive the auction clearing price. Under floating feeding premium, the price is a combination of the generation output, strike price and market reference price (Goverment of Ireland , 2020).

7.3.2 Community Energy Efficiency

Currently, better energy community programme is available for energy efficiency projects with funding up to 20 million Euros for 2020 (SEAI, 2020). This support is available for residential and non-residential users with the main aim of reducing the use of fossil fuels, energy costs and GHG emissions (DCCAE, National Energy Efficiency Action Plan 2017-2020, 2017). The scheme supports two main energy efficiency measures such as retrofitting, and integration of renewable energy resources (SEAI, 2020).

The criteria for the project evaluation are as shown in the below Figure 7-1 (SEAI, 2020). A case study for community owned energy efficiency project is presented in chapter 8, where some of the main criteria shown below will be reflected in the case study regarding community owned energy efficiency projects in chapter 10.

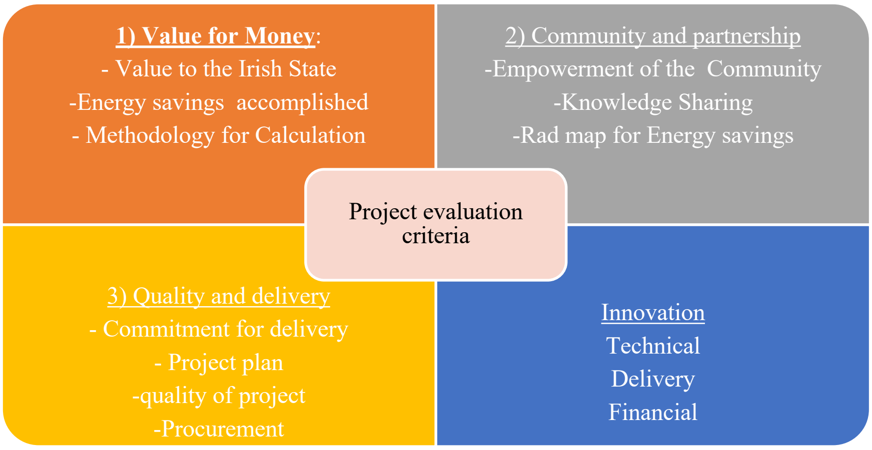


Figure 7-1: Project evaluation Criteria for Better Homes (Source: SEAI)

7.4 Transport Sector

7.4.1 Private Transport

A grant for Electric Vehicles (EV) is offered by SEAI. There is a list of eligible plugin hybrid (PHEV) and battery electric vehicles (BEV) that are available on the Irish market. This grant is only available for new vehicles and the amount of the grant depends on the price of the EV (SEAI, 2017).

There are some additional financial incentives to switch to an EV. Direct CO2 emissions values are used to calculate the Vehicle Registration Tax (VRT) and annual Motor Tax Bands for vehicles (SEAI, 2017). EV receive VRT relief separately to SEAI grant, this support for BEVs is in place until the end of 2021 and for PHEVs until end of 2020 (SEAI, 2017).

Privately bought EV

When purchased for a private use; the maximum grant available is 5,000 Euro. To receive a grant the price of the vehicle should not be lower than 14,000 Euro (SEAI, 2017). There is also a grant for up to 600 Euro for the purchase and installation of an electric vehicle home charger unit. This grant is for new EV or bought second hand from 01/01/2018 (SEAI, 2017).

Commercially bought EV

The grant provided by SEAI for business and public entities are for the purchase of N1 category EV, which are commonly small goods carrying vans with a technically permissible maximum mass not greater than 3,500 kg (SEAI, 2017). When purchased commercially, the maximum grant available is 3,800 Euro. To receive a grant the price of the vehicle should not be lower than 14,000 Euro (SEAI, 2017).

7.4.2 Public Transport

Local Link is the Rural Transport Programme that operates on behalf of the National Transport Authority of Ireland (NTA) and it is run by local boards. Local Link outsources rural transport services to private operators (NTA, 2018). Clare Bus is providing services for the Loop Head area under the Local Link Limerick Clare which covers the Clare County.

According to the County Clare development plan 2017-2023, public transport needs to be increased to minimise emissions of greenhouse gases and avoid human-induced global climate change. In addition, this plan states that population should opt for public transport to go to work and school in order to maximise sustainable modes of transport and provide for ease of movement for all the users of the road (Clare County Council, 2017).

8 Pre-feasibility study for Buildings

8.1 Residential

One of the main team objectives is to give an insight for building owners in Loop Head in order to make their buildings more energy-efficient. The prefeasibility study includes three main steps of upgrading the energy performance of the house: the first step is the insulation of walls and roof, the second step is upgrading/changing the existing heating technology and the last step is to install a rooftop solar PV system.

The team conducted several interviews with owners of different house types of which a sample household has been selected for a pre-feasibility study. The selected household illustrated in Figure 8-1 is a bungalow concrete-block house with cavity walls. The dwelling was constructed in 1992, and it has two floors with an approximate floor area of 120 m^2. The main source of heating is a central oil-fired system with 60% annual average efficiency (data is collected from the interview).

Figure 8-1: Selected household for the pre-feasibility study, Kilkee Co Clare, IC team member feb.2020

For the insulation of walls and roof, the building owner should know the construction of the building element and the correspondent U-value[11] in order to know the amount of heat loss from different fabric and to select the suitable type of insulation. As illustrated in Table 8-1 below, the U value of each building elements is taken from the European building typology TABULA, which includes a number of representative building types for Ireland (TABULA, 2014). This way, typical energy performance of buildings can be estimated without in-depth studies. The building dimensions are taken from the conducted interviews and heat losses are calculated accordingly (methodology and calculations are provided in excel file).

[11] U Value measures the effectiveness of the material as insulator, the lower the U-value of a building element building's fabric the better it performs as insulator and the less energy is required for heating

Table 8-1 Building elements U Values and the correspondent heat loss

Building Element	**U-Value (W/m^2K)**	**Area (m^2)**	**Current heat loss (MWh)**
Cavity walls	0.6	103	2.9
Pitched roof	0.4	122.3	2.3
Solid floor	0.64	143	3.6
Double glazed windows, PVC frame, 6mm gap	3.1	18.9	2.7
Solid wooden door	3	2	0.3

Note: 43% of heat loss is due to the poor insulation in roof and walls

- **Cost of wall and roof insulation, payback period and amount of heat demand reduction after insulation of the house**

The selected building is a detached house constructed in 1992, which is similar to the building type IE.N.SFH.07.GEN, constructed between 1983-1993, in the TABULA brochure. The required insulation material for the selected building and the total estimated cost of insulation is calculated based on (TABULA, 2014). The reduced heat loss for the house after insulation, saved fuel costs and the payback period is also calculated.

Since the walls of the selected house are cavity walls, they can be insulated according to (TABULA, 2014) by "filling the cavity with beads, with combination of dry lining/internally insulating with 82.5 mm thermal laminate boards" and the cost is 34.43 Euro/m^2. With this insulation, the U Value for the wall will be reduced to 0.21 W/m^2K. The roof can be insulated by adding 200 mm mineral wool and that will cost 8.23 Euro/m2 achieving a U value of 0.13 W/m2K. According to (SEAI, 2020) the available grant value of attic insulation is 400 Euro, while for the internal insulation (dry lining) it is 2,200 Euro. The reduced U value after insulation for the roof and wall will appear as a decrease in heat loss. The total heat demand of the house of 17 MWh can be reduced to 11.5 MWh. Table 8-2 below summarizes the cost for each insulation, savings in terms of heat and money and the payback period. The detailed calculation of the estimated cost and the reduced heat loss is shown in attached excel file for the residential sector.

Table 8-2: Insulation cost, saved heat and money after insulation and simple payback period

Insulation Type	Estimated cost of insulation after applying grant [Euro]	Reduced fuel demand [MWh]	Estimated savings [Euros]	Simple payback period (Years)
Wall insulation	1,346	3.02	223	6
Roof insulation	607	2.54	188	3

Note: Replacing windows will save 1.5 MWh heat, but the payback period is almost 50 years, so it's recommended to change it when it is a must, for example, the money can be invested in upgrading the heating system.

- **Cost of wall and roof insulation, payback period and amount of heat reduced after insulation for stone and timber frame houses**

Different building types require different insulation materials; therefore, two more building types are considered: stone and timber frame houses assuming that they are using the same oil-fired heating technology. Their characteristics are selected from (TABULA, 2014).

From the calculations, it's noticeable that the older the house the higher the primary energy demand is. Due to the improper insulation, the cost of insulation is higher. As we can see from Figure 8-2 the stone house, which was constructed pre-1900 has a higher energy demand compared to the timber house which was constructed in 1994-2004. Both houses have different upgrading steps and different cost. According to (TABULA, 2014) the stone house will require the application of external insulation with a thermal laminate board and that will cost approximately 8,272 Euro and mineral wool insulation for the roof with an approximate cost 832 Euro. The timber frame house is already rather well-insulated. (TABULA, 2014) suggested the insulation of the roof by adding mineral wool; and the insulation cost will be 623 Euro.

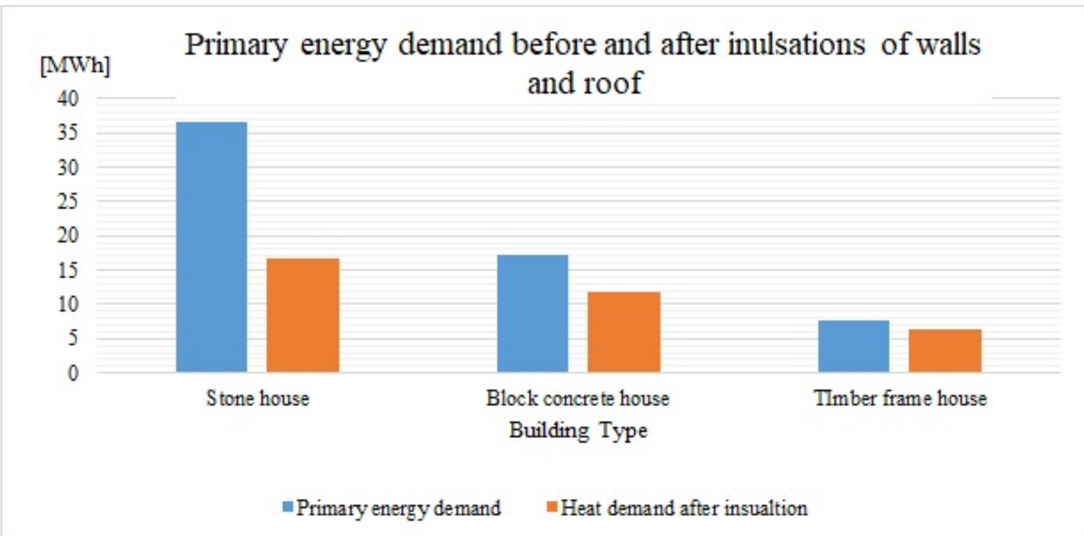


Figure 8-2: The primary energy demand before insulation and save energy after the insulation.

The estimated payback period is different for each building type and it depends on the cost of the applied type of insulation material and the obtained savings. Figure 8-3 below shows the different simple payback periods for the 3 types of building.

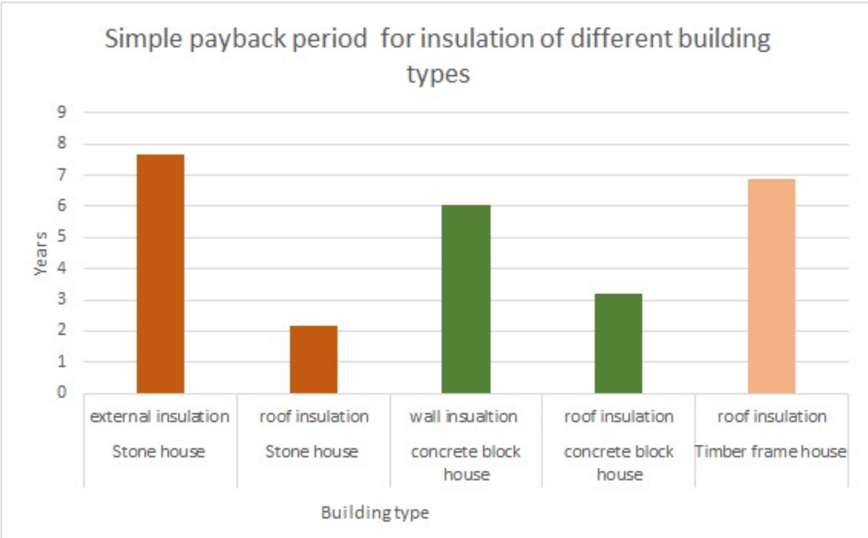


Figure 8-3: Payback period for insulation of different building types

8.1.1 Heating technology upgrading in the retrofitted house

After the concrete-block house is retrofitted the next step is to upgrade the existing heating technology which is-as mentioned earlier oil-fired central heating with 60% efficiency. The cost of the heating fuel (kerosene) is 0.74 Euro/liter. The total heating demand after insulating the house is 11.56 MWh, 10.09 MWh is accounted for space heating, the peak monthly heat demand is 1.66 MWh.

The house was constructed in 1992 meaning that the heating system is already 28 years old and probably needs to be replaced. Several heating technologies with different efficiencies and prices are available and can be suitable to install, in this section two clean heating technologies are provided: an air-to-water heat pump and a wood pellet boiler.

An air-to-water heat pump can be considered as one of the clean options for heating the house. The total heat demand required for both space and water heating can be covered by a 7.5 kW air-to-water heat pump, which has efficiency coefficient of performance (COP) of 3.25, meaning that one unit of electricity generates 3.25 units of heat. The air-to-water heat pump consumes electricity, so in the fuel calculations an average electricity price for the households of 0.23 Euro/kWh is considered (SEAI, Domestic fuels comparison of Energy cost, 2020). The total investment cost of an air-to-water heat pump is 13,125 Euro (Danish Energy Agency, 2020), considering a grant from (SEAI, 2017) of 3,500 Euro, the final investment cost of the air-to-water heat pump is reduced to 9,623 Euro. The simple payback period of the system is 26 years (compared to oil-fired system).The main advantage of an air-to-water heat pump system is it's high efficiency, while the noise can be a disadvantage of the system (Danish Energy Agency, 2020).

A wood pellet boiler also can be considered a climate-friendly option for heating the house. As illustrated in Figure 8-4, the wood pellet boiler heating technology produces 5 times less CO_2 emissions compared to the existing oil-fired heating system (7 Energy, 2020) followed by the heat pump which is 3 times less, also from the graph it can be noticeable that the retrofitted house produces less CO_2 compared to the not retrofitted one.

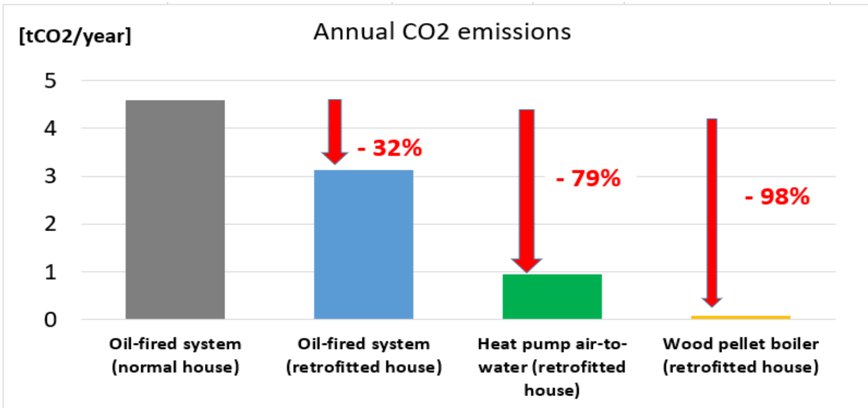


Figure 8-4: Comparison CO_2 emissions from oil-fired and heat pump air-to-water heating systems.

The total cost of a 10 kW automatic stoking wood pellet boiler is 5,830 Euro (Danish Energy Agency, 2020) (there are no grants available from SEAI). This excludes the necessary fuel storage and handling. The efficiency of a wood pellet boiler is 75%. The fuel cost for wood pellets is 0.06 Euros/kWh (SEAI, Domestic fuels comparison of Energy cost, 2020). The simple payback period of the biomass boiler technology is 36 years. In terms of fuel savings compared to the existing oil boiler in the retrofitted house air-to-water heat pump saves 372 Euro/year and wood pellet boiler saves 266 Euro/year.

Table 8-3: Economic parameters of heating technologies (methodology and calculations are provided in excel file)

	Heat pump air-to-water	Biomass boiler (wood pellets)
Installed capacity [kW]	7.5	10
Investment [Euro]	9, 625 (13 125)	5 ,830
Fuel cost [Euro/year]	500	606
Payback period [year]	26	36
Efficiency [%]	325	75

Note: The investment cost of the heat pump air-to-water without SEAI grant 8,069 Euro.

Assuming that the old oil-fired heating system needs to be replaced, wood pellets biomass boilers could be a suitable solution in this case, because of the comparable less investments. On the other hand, in case of installation of wood pellets biomass boiler a space for wood pellet storage is required (Danish Energy Agency, 2020).

8.1.2 Rooftop solar PV system installation in the houses

As it was observed from the conducted interviews, the installation of rooftop solar photovoltaic (PV) system is getting a lot of interest among the people of Loop Head. The team decided to simulate two options of installing 3 kW and 9 kW solar PV systems without batteries, and calculate the profitability of each option for homeowners. For the simulation of a rooftop solar PV system, a selected household consumes 4.12 MWh/year of electricity and 1.47 MWh/year of water heating. As mentioned before, a selected household uses an oil-fired central heating system for both space and water heating. The average total roof size area of the selected house is 120 m^2. It should be highlighted that a rooftop solar PV system generates electricity. The simple description of how the rooftop PV system works is shown in Appendix 3.

Using modelling tool HOMER, the rooftop solar PV[12] system is simulated based on this approach: solar PV panels generate electricity during daylight hours and this electricity is used to cover home electricity needs. In case there is no electricity demand in the house, the excess of electricity generated from PV panels can be used for domestic water heating (to heat a 300-liter hot water tank). The limitation of this method is that the daily load profile for the house is selected from the HOMER library and does not necessarily represent local conditions. It should be mentioned that the amount of electricity generated from PV panels depends on a range of factors including the efficiency of PV panel (19%) (Solartricity, 2020), size of the system, orientation and pitch of the roof, and the geolocation of the house (global horizontal irradiance of Loop Head is 971 kWh/m^2/y). During the night, the PV panels will not generate electricity and during the day the electricity will vary, meaning that the demand will not always be met.

- **The cost and payback period of 3 kW rooftop solar PV system**

The simulated 3 kW rooftop PV system consists of 10 panels (each panel is 300 W) and a solar inverter of 2.5 kW. The annual electricity output from PV panels accounts for 2,900 kWh/y, of which 1,426 kWh/y covers electricity needs for the house; 1,075 kWh/y goes for the domestic water heating; and 406 kWh/y is excess of electricity. The share of electricity generation from solar PV system is 35%, and the share of water heating in the house consumption provided by solar PV is 73%. The total cost of the system includes the cost of PV racks and installation cost equal to 3,249 Euro (Solartricity, 2020), (Alma Solar, 2020), (Wholesale Solar, 2020). Considering the new changes to domestic solar PV supporting scheme after installation of a 3 kWp system, it is possible to receive 600 Euro grants (SEAI, 2019).

[12] Solar panels need to be located on the South facing roof

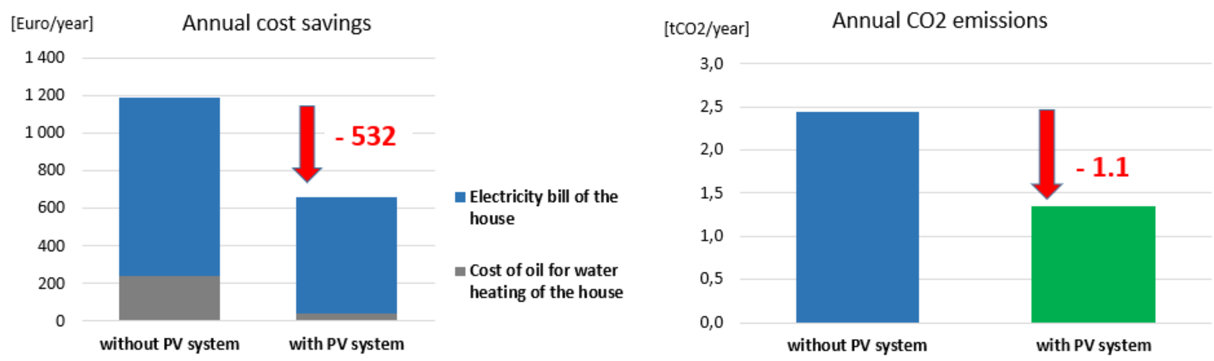


Figure 8-5: Annual saving and CO2 reduction with rooftop solar PV installation (3 kW)

The total cost of the system after receiving the SEAI grant is estimated at 2,649 Euro. Taking into consideration the annual savings of electricity consumption, less use of oil for water heating and opportunities to sell electricity to the grid, the payback period of the system (including 5% interest rate) is 8 years. As shown in Figure 8-5 the highest saving of electricity bill is observed accounting for 328 Euro/year, the saving of oil is equal to 204 Euro/year. From the graph above there's a reduction on CO_2 emission from the house to 1.1 tCO_2/year.

- **The cost and payback period of 9 kW Rooftop solar PV system**

A 9 kW rooftop solar PV system requires 49 m^2, which is equal to 50 % of the roof size of the selected house. The simulated 9 kW rooftop PV system consists of 30 panels (each panel is 300 W) and solar inverter 8 kW. In this scenario the case when there is no domestic electricity and water heating demand is considered, the excess of electricity generated from PV panels can be sold to the ESB grid operator.

Annual electricity output from PV panels accounts for 8,722 kWh/y of which 1,885 kWh/y covers own electricity needs of the house, 1,388 kWh/y goes for water heating of the house and 5,450 kWh/y is excess of electricity which could be sold to the grid if a feed-in premium of tariff was available. The share of electricity generation from solar PV is 46% and the share of water heating in the house consumption provided by solar PV is 94%. The total cost of the system includes the cost of PV racks and installation cost of the system equal to 6,899 Euro (Solartricity, 2020), (Alma Solar, 2020), (Wholesale Solar, 2020). As shown in Figure 8-6 the installation of a solar PV system can significantly decrease home electricity bill 433 Euro/year and save oil for 230 Euro/year. From the graph below we can see also that it is possible to reduce CO_2 of the house to 1.44 tCO_2/year.

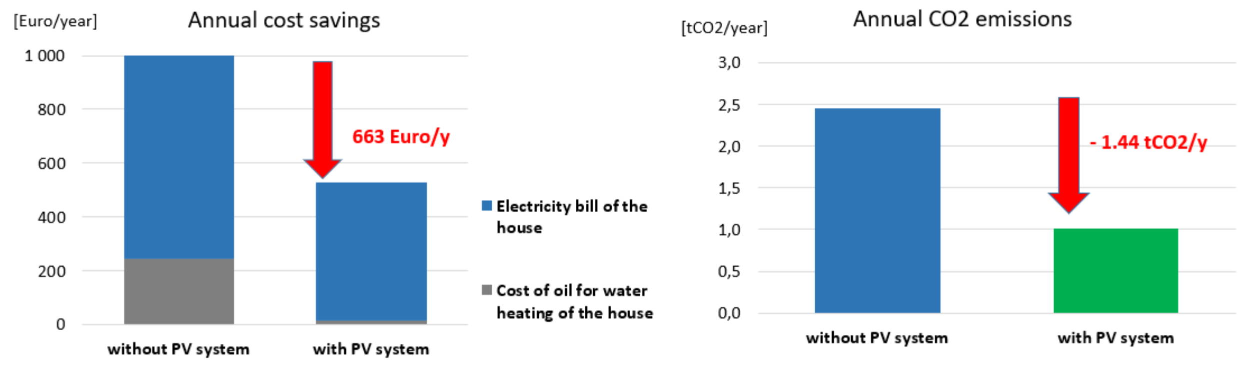


Figure 8-6: Annual saving and CO2 reduction with rooftop solar PV installation (9 kW).

In case "Feed-in-Tariff" will be introduced in Ireland at a price of 0.066 Euro/kWh (La Monaca S., Ryan L., 2017) the payback period of the system (the annual savings of electricity consumption, less use of oil for water heating) is 13 years. Based on conducted calculations, the payback period of the 9-kW rooftop solar PV system will be less than 6 years only if the "Feed-in-Tariff" will be 0.19 Euro/kWh.

8.1.3 Conclusion

The pre-feasibility study provided supporting materials for homeowners of Loop Head to help them retrofit their houses change their heating system technologies and install rooftop solar PV systems. For the selected house (concrete-block) the estimated cost of wall and roof insulation after applying the available grants from SEAI is around 2,000 Euro and for the stone house it is around 9,000 Euro, while for the timber frame house the cost of roof insulation is 624 Euro. The next step after retrofitting the house is replacing the existing heating technology. For those homeowners who are looking for comparably climate-friendly heating technology, the option could be the installation of a wood pellet boiler, which costs 5,830 Euro. The second option could be an air-to-water heat pump, which cost after SEAI grant 9,623 Euro. The 3-kW rooftop solar PV system can meet 35% of the electricity demand of the house and 73% of water heat demand. The total cost of the PV system after the SEAI grant is 2,649 Euro with 8 years payback period. In case the Government of Ireland introduces the Feed-in-Tariff at a price of 0.066 Euro/kWh a 9-kW rooftop solar PV system can be installed at a cost of 6,899 Euro with a 13 years' payback period. If the Feed-in-Tariff is as high as 0.19 Euro/kWh the payback period will be 6 years. By focusing on these three steps: house retrofitting, changing the heat technology and installing rooftop solar PV panels there's a great potential for the homeowners to save energy, money and to positively impact the environment.

8.2 Hotels and B&Bs

As a tourist destination Loop Head's business sector is driven by accommodation services. Apart from holiday homes, hotels and B&Bs are common accommodation services that are available in the area. The International Class program conducted a research of opportunities in Hotels and B&Bs for energy efficiency and renewable energy.

8.2.1 Case study for a hotel in Loop Head

Current energy demand

For the hotel case study, based on interviews with local hotel owners, it is can be estimated that a typical hotel in Loop Head has approximately 20 rooms with a total floor area of 730m^2 .The energy demand of the hotel is described below:

Table 8-4: Typical hotel energy demand in Loop Head

Purpose	Fuel Type	Fuel consumption (MWh)
Cooking/Restaurant	LPG	19.3
Water and space heating	LPG	114
Appliances	Electricity	286

The hotel is currently fulfilling its heating demand with central heating system running on LPG, and electricity demands are solely covered by the public grid.

Problem Background

From the interview with hotel's owners, high energy expenses have been identified as one of the main concern for the business. On yearly basis, the hotel spends 41,000 Euro per year for electricity and 13,000 Euro for gas water and space heating (Including consumption from hotel's restaurant).

The revenue of the hotel depends highly on the seasonality with high occupancy rates during the summer months and lower in other season especially winter. However, the spending for heating demand is higher during winter due to lower outdoor temperature. This has raised an open question on what can be a more cost-efficient heat supply system that can potentially cut heating costs. The annual spending on electricity, at the moment, is also relatively high. Therefore, a potential technology to help cut electricity bills is also highly desirable.

Analysis of Alternative Technology

The evaluation of alternative heating technology is conducted with a self-built financial analysis model together with different digital optimization tools (E.g. Homer)

The methodology for the financial analysis model is explained below:

- First, the designed capacity for the system is calculated based on the peak monthly heating demand of the hotel.
- The investment cost is then determined based on a breakdown of costs for different technologies (Information on costs and efficiencies of different heating technology are included in the annex).
- New fuel consumption related to specific technology and total fuel costs are then obtained from the demand derived by the technology efficiency.
- A cash flow analysis of the investment is then conducted with revenue calculated as the saved fuel cost.

The result of the calculation for switching heating technology are described below:

Table 8-5: Calculation of Heating Technology for Hotel

New heating technology	Efficiency of heating technology (%)	Current cost for heating (Euros/year)	New heating fuel	Investment cost (Euros)	New fuel cost for heating (Euros/year)	Simple payback Period (Year)
Heat pump, Air-to-water	325%	13,000	Electricity (Commercial)	53,500	4,100	6
Biomass boiler	83%	13,000	Pellet	30,000	8,600	7
District heating from AD plant	100%	13,000	District heating	10,000	11,700	Approx. 8

The methodology to calculate figures in above table is explained below:

- *Current cost = (Total gas demand x LPG price).*
- *Heating demand = LPG consumption x 85% boiler efficiency*

To determine the investment cost of the heating technology, at first it needed to define the capacity of the system by the following equation:

- *Required Capacity = (Peak month heating demand/720 hours of the month) x a factor of 2*

The factor of 2 is used to ensure that the designed capacity can still supply indoor heat even when outdoor temperature drops to the annual minimum.

The investment cost then defined as follows:

- *Investment cost = Designed capacity x Heat pump price/kW, with the price of 1750/kW*

The new fuel heating cost is determined with following step:

- *New fuel heating cost = (Total heating demand/COP or efficiency of heating system) x fuel price*

All the prices for fuel are summarized and attached at the annex of this report.

From the result table, it can be witnessed that an air to water heat pump is the most cost-efficient option to provide heating services for the hotel. The COP of a heat pump, however, is highly dependent from how well the building is insulated; so the better the building insulation, the less electricity consumption is needed to provide one unit of heating, resulting in low operation cost. Switching to a biomass boiler that consumes wood pellets will have a little longer payback time. However, since pellets are a renewable energy source and has better CO_2-emission factor compared to electricity, it is more environmental friendly to a biomass boiler.

Switching to district heating will be more expensive since it is also needed to cover the cost of the connection. There are also high uncertainties with the connection cost and the district heating tariff for the fuel cost calculation, which is here assumed to be 120 Euro/MWh, and which highly depends on the production cost of local district heating.

Since electricity accounts for large proportion of total energy bill of the hotel, as mentioned above, we also considered to simulate and design a solar PV rooftop system, which allows the hotel to self-generate their electricity. By using Homer software as an optimization tools, the designed system is proposed at 40 kWp, which would cover 208 m^2 (less than half of total roof area) and has the lowest levelized cost for electricity production as possible.

The calculation result is shown below

Table 8-6: Solar PV calculation result for Hotel

Total roof size (m2)	PV power production (kWh/yr)	Total PV power consumed (kWh/yr)	Total investment (€)	Total saving (€/yr)
208	38800	38120	40600	5300

The total saving of the systems is calculated by:

- *Saving = Power consumed x Price of electricity*

Conclusion

From the current case study, it can be witnessed that the Hotel sector in Loop Head has a high possibility to reduce their energy expenses by switching to a more efficient heating technology or to install solar PV rooftop for self-consumption. Switching to a heating technology and implementing solar PV will not only help cut down energy bill but also reduce carbon footprint.

It is also important to stay aware that hotels are different in buildings types and business' structures. To be able to provide more precious and trustworthy calculation for technology selection, a detailed energy audit for each individual building has to be conducted which is not possible during the scope of this study.

8.2.2 B&B Case Study

Current Energy Demand

From the interview with local B&B's owners, it can be identified that a typical B&B in Loop head offers 4 guest bedrooms with an estimated floor area of 544 m^2. The B&B comprises of two main parts, a residential area where the owners' family lives, and a B&B part, which is opened for business. There are often common areas in between. The current energy demand of the building is presented as below:

Table 8-7: B&B Energy Demand

Purpose	Fuel Type	Fuel consumption (MWh)
Water and space heating	Oil (Predominant fuel)	38
Appliances	Electricity	8.1

The predominant source for heating of B&B is oil with supplement with locally produced peat/turf which is used for the fireplace.

Analysis of Alternative Technology

The relatively low price of kerosene compared to other heating fuel such as LPG and electricity has make most heating technology economically feasible to deploy. Also, the biogas district heating is not available for all B&Bs because B&Bs' locations are spread out and to extent district heating pipeline to each individual hotel are not economically feasible.

To be able to make investment for more environmental friendly heating technology such as heat pump to breakeven, high amount of subsidies for investment cost need to be granted.

The financial analysis for an investment of air to water heat pump for B&B is presented below

Table 8-8: Calculation of alternative heating Technology for B&B

New heating technology	Efficiency of heating technology (%)	Current cost for heating (€/year)	New heating fuel	Investment cost (€)	New fuel cost for heating (Euros/year)	Subsidy size to breakeven (€)
Heat pump, Air-to-water	325%	2,800	Electricity	16,500	2,250	8,200

A relatively more cost efficient for B&B is to deploy solar rooftop PV with implementation of electric sensor which allows using excess electricity produced from PV system to power immersion boiler. Similar to the case of hotel, the research team also run optimization simulation tool to define the best capacity for the PV system. The objective function for the optimization is the production cost for power from solar PV will be lower than current power tariff, the total size of the system will not cover more than half of the roof and the excess electricity is minimized to avoid wasting energy. After simulating by computer program, the proposed size of the system size is 8 kWp which require a roof area of 42 m^2.

The results of the simulation are described below:

Table 8-9: Solar PV Calculation result for B&B

PV power production (kWh/year)	Total PV power consumed for electricity consumption (kWh/year)	Total PV power consumed for hot water consumption (kWh/year)	Total investment (€)	Total savings(€/year)	Payback Period (Year)
7750	3070	3150	8,100	980	8

Which the total saving of the systems is calculated by:

- *Saving = (power consumed x price of electricity) + (total power for hot water/85% x oil price)*

Conclusion

From the case study with a typical B&B, it can be concluded that the most economical viable technology to deploy for B&B is solar PV rooftop with option to make use of excess electricity to cover hot water demand. Low-cost oil price is currently the major constraints avoiding B&B to switch to more energy efficient and environmental-friendly technologies such as heat pump or biomass boiler. On the other hand, the current calculation has not taken into account future possibilities when oil price can become much higher and technology costs for heat pump and boilers becomes cheaper to deploy.

9 Prefeasibility study for Farming Sector

9.1 Anaerobic Digester

An anaerobic digester is a technology to produce renewable energy from a biological process where microorganisms in the absence of oxygen break down biodegradable material. The result of the process is biogas and digestate, a nutrient-rich fertilizer. Biogas can be turn into energy (heat or electricity) or can be upgraded, by removing the CO_2, to biomethane. This biomethane can be injected into the gas network or it can be stored on site and then transported by container to off grid gas users or use as a vehicle fuel at an on-site fuelling station (SEAI, 2017). The figure below presents the basic process considered in AD technologies.

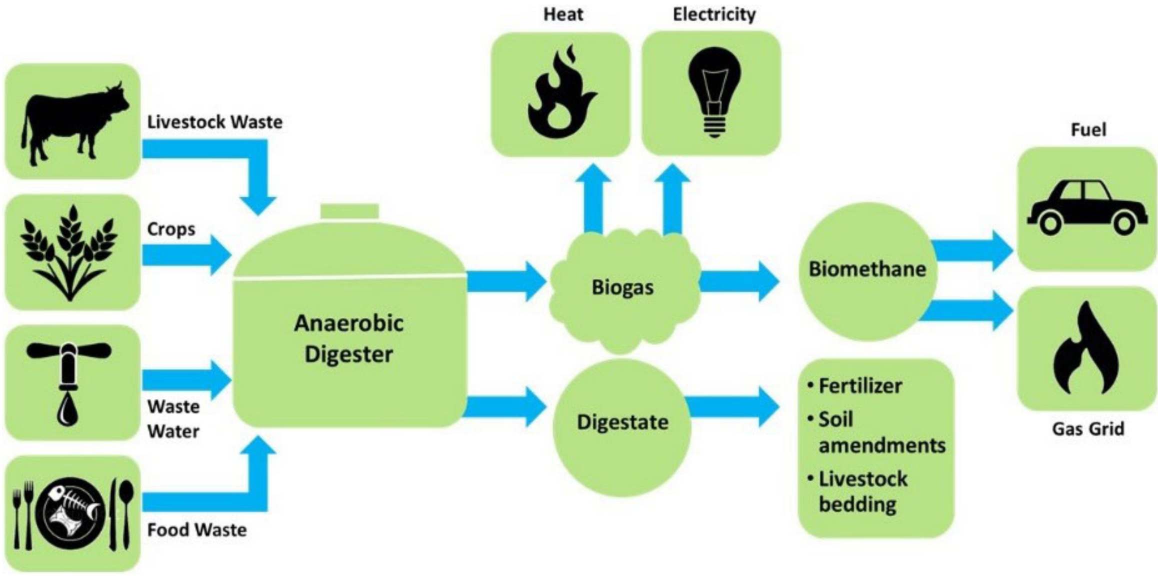


Figure 9-1: Anaerobic digestion technology (Environmental and Energy Study Institute (EESI))

9.1.1 Benefits of producing biogas through Anaerobic Digestion

Biogas has a wide variety of uses and benefits some of them are:

- The digestate, which is a nutrient-rich substrate produced by anaerobic digestion, can be particularly beneficial for farmers by improving the value of the slurry as a fertiliser. Also the volume of the digestate will be around 90% to 95% of what was fed into the digester (NNFCC, 2020). An income from selling degassed slurry as improved fertiliser of 0.8 Euro/ton (Brian H. Jacobsen F. M., 2013) input is considered in the financial calculations.
- AD presents an opportunity to improve slurry management and address the issues arising from traditional management methods. It can reduce the odours from slurry spreading as the odour of digestate is significantly less (SEAI, 2017)
- Biodiversity can be improved due to the lower pathogen storing in digestate compared to slurry (SEAI, 2017).
- Methane (CH_4) is a worse greenhouse gas than Carbon dioxide (CO_2) by a factor of 21 (Deublein & Steinhauser, 2011) per kg released. Therefore, harnessing the methane can reduce the environment impact in the farming sector.

9.1.2 Scenarios 1 and Scenario 2

During the development of the case studies, three scenarios were considered according to agricultural feedstock present in the region, technology and output. Table 9-1 present the summary of the cases:

Table 9-1: Scenarios considered in the AD prefeasibility study.

	Technologies used with the anaerobic digester	**Agricultural feedstock**	**Output**
Scenario 1	Gas boiler	Slurry	Heat
Scenario 2	Combined heat and power (CHP)	Slurry	Heat and electricity
Scenario 3	Upgrade to biomethane	Slurry and silage	Biomethane

According to the analysis done in the section 5.3, a total of 952 thousand cubic meters of biogas, with a total energy content equivalent to 5.71 GWh per year, can be used to produce heat or power. Table 9-2 summarizes results of the scenarios based in own calculations. In the case of the boiler, an efficiency of 90% is assumed. In the CHP engine, the energy is converted into usable energy; in this process losses are present. The following table shows that in total approximately 90% energy could be used: 35% mechanical energy (electricity), 55% usable heat, while 10% are losses, (Rutz D. , 2015). Additionally, it is assumed that the AD needs 20% of the heat produced to allow bacteria a faster decomposition of the feedstock (Rutz D. , 2015).

Table 9-2: Outputs of the scenarios that consider heat and power. Source: Own calculations

Scenario	**Technology**	**Efficiency (%)**	**Total heat used in the anaerobic digestion process (GWh_{th}/year)**	**Total heat output (GWh_{th}/year)**	**Total electricity output (GWh_{ele}/year)**
1	Gas boiler	90	1.02	4.1	0
2	Combined heat and power (CHP)	90	1.02	2.1	1.99

In order to compare these two scenarios, the levelized cost of heat (LCOH) give a metric that allows the comparison of the combination of capital costs, operation and maintenance cost and performance of the two systems. It is the minimum cost of heat above which the project becomes feasible.

The results in scenario 1 present an LCOH 12.3 cents/kWh. On the other hand, scenario 2 is most costly per every unit of heat produced with 18.93 cents/kWh. The reason mainly relies in the capital cost difference between the two technologies and the reduced thermal output of the CHP. Moreover, there is no any active tariff for biomass-based electricity when this study was performed. Therefore, CHP technology is not considered viable in a community heating project trough district heating unless the option of a feed-in tariff arises or a sufficiently large consumer is found.

9.1.3 Scenario 3 – Upgrade to Biomethane

This scenario is designed to show the maximum biogas/biomethane production that could be achieved through anaerobic digestion.

For this scenario a mix of 40% silage and 60% slurry was considered, this a frequently mix used in anaerobic digestion since the water and dry matter proportion has to be taken into account.

Considering that the total technical potential of slurry is used, and this will represent the 60% of the mix; around 35% of the technical potential of silage is needed to cover the other 40% of the mix. Considering the heat needed for the AD, a total of 1,269 thousand m^3 of useable biogas can be obtained to be upgraded to biomethane.

There are five available technologies for upgrading biomethane; some are less commercially mature than others. The most common technology is water scrubbing in which the biogas is put in contact with water by spray or bubbling to wash out the CO_2. One advantage is that no further compression is necessary for injection of biomethane into the gas grid (Danish Energy Agency , 2017).

If water scrubbing is used, an efficiency of 99% is considered, in the process a small portion of the methane leaks. Bearing in mind that 0.2 kWh per m^3 of raw biogas is needed for the operation, equal to 4.3% of the energy total content and assuming methane content of 60% (Danish Energy Agency , 2017), around 83.3 m^3 of biomethane per hour can be produced. There is also an output of waste gas containing mostly CO_2. Table 9-3 summarizes the results for scenario 3.

Table 9-3: Outputs of the scenario 3 – Upgrade to Biomethane. Source: Own calculations

Scenario	**Technology**	**Efficiency (%)**	**Total biogas output (m^3 raw biogas/h)**	**Total biomethane output (m^3CH4/h)**
3	Water Scrubbing	99	138.6	83.3

Even though one of the advantages of upgrading biogas is that it is not dependent on the local heat demand, biomethane is only cost effective at high capacities, because of its large investment cost and electricity consumption connected to the upgrading technology (Danish Energy Agency , 2017).

Typical capacities in Germany for example, are from 500 to 1,400 m^3 raw biogas per hour, in Denmark is in the range of 1,000 to 2,000 m^3 of biomethane per hour (Danish Energy Agency , 2017). While using all the practical potential of silage, the total biomethane output is still too low find a technology that can process the biogas at small scale.

9.1.4 Location selection criteria:

To select the Anaerobic Digestion (AD) plant location, social, economic and technical aspects were considered. In this section, an overview of the selection criteria for the location of the AD will be provided. In total, 4 possible locations for the AD plant were considered based on the following criteria:

1) **Technical aspects:** The basic concept for the design of the AD is to cover local heat demands. The figure below shows the mapping of domestic space heat demand using ArcGIS based on the calculations presented in the residential sector. It can be observed from the figure that highest domestic space heat demand is in Kilkee (2,178 MWh/year), Carrigaholt (1,128 MWh/year) and Querrin (1,043 MWh/year).

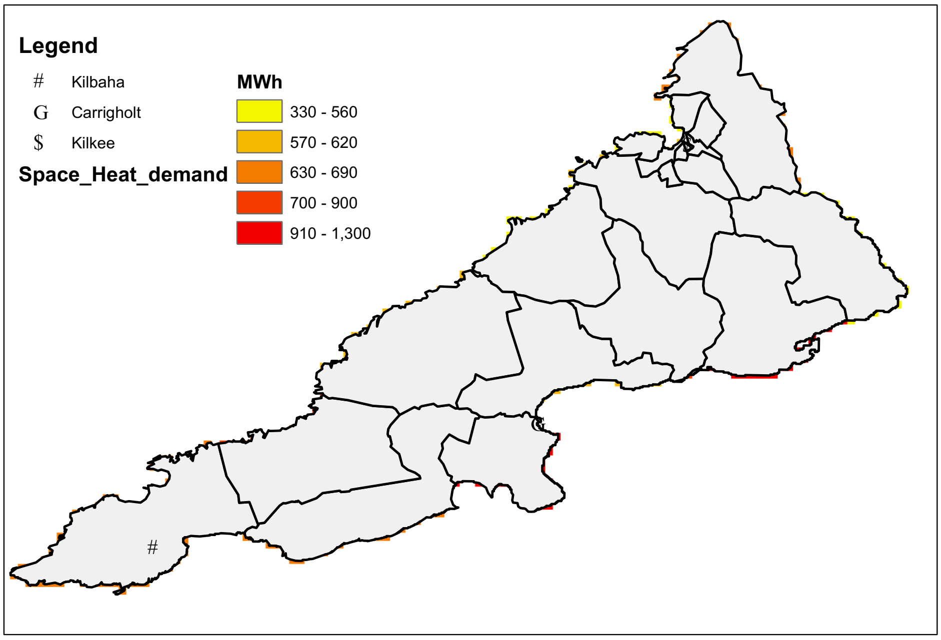


Figure 9-2: Domestic Space heat demand Loop Head (Data source: Authors calculations, simulated using ArcGIS)

In addition to the demand from residential sector in Kilkee, there is a high heat demand from the commercial sector, as has been illustrated in previous sections. Specifically, "Water World", which amounts to 147.8 MWh during its three months of operation and the demand from the hotels which amounts to 715.7 MWh/year. Accordingly, areas around Kilkee are considered as a possible location for the AD as they will be close to the demand side.

2) **Economic aspects:** As been presented in chapter 5, most of the farms are located in the areas around Carrigaholt. Thus, it was important to consider a possible location around Carrigaholt as to analyse the optimization of the transport cost of the feedstock to the AD plant. As such, a location near Carrigaholt was considered. The distance to the demand side needed also to be taken into consideration due to the piping cost. Thus, two central locations between Kilkee and Carrigaholt were considered with one closer to Carrigaholt and the second closer to Kilkee.

3) **Social aspects**: The regulations mentioned in (Irbea, 2017), stating that bioenergy structures should not be within 200 meters from residential areas and 10 meters from public roads, were ensured by constructing 200 meters buffers around Kilkee and Carrigaholt and 10 meters buffer around the roads. As no data could be found regarding the building's distribution outside of Kilkee and Carrigaholt, the distance from the possible AD structures was ensured by manual measurements using imagery as a base map. The main wind direction is WSW as illustrated in chapter 5 in the wind resource assessment section (will be added), was also considered when choosing the locations as to avoid potential smell. The table and the figure below summarize the possible four locations for the AD plant and the criteria of selection.

Table 9-4: Selection criteria for AD locations

Location	Close to demand	Close to supply	Regulations considered	Wind direction considered
AD Location 1	✓	✓	✓	✓
AD Location 2	✗	✗	✓	✗
AD Location 3	✗	✓	✓	✗
AD Location 4	✗	✓	✓	✓

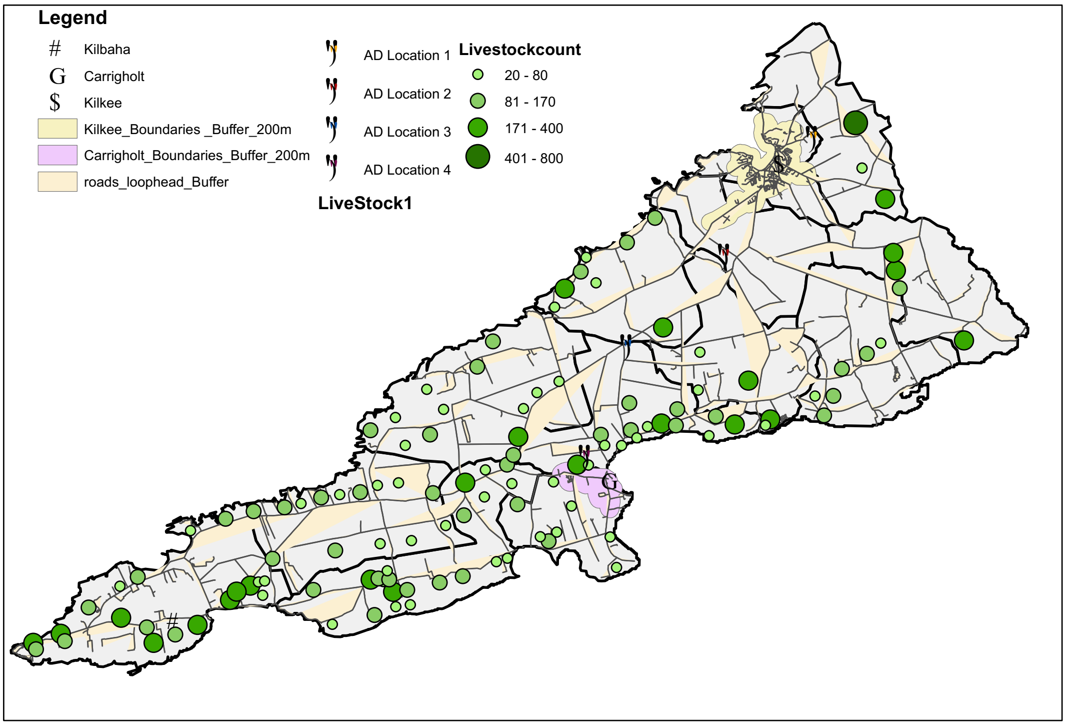


Figure 9-3: AD possible locations (Data source: (Geofabrik , 2018) cattle distribution based on farmers estimation, *mapped using ArcGIS)*

Transport optimization for location selection:

As the economic aspect will have a considerable impact on the investment due to the transport and piping costs whether using district heating or gas pipes, an optimization between the transport piping costs was analysed for all four locations. The methodology followed is shown in the below figure. Straight line distance generated from ArcGIS were adjusted by a factor 1.5 and multiplied by 2 to account for round trip road distance. District heating piping calculations were based on 400 Euro per meter for a pipe capacity of 0.5 MW (ETSAP, 2013); gas piping cost of 93 Euro per meter (Brian H. Jacobsen F. M., 2013); and transport cost of 0.061 Euro per ton km (Brian H. Jacobsen F. M., 2013).

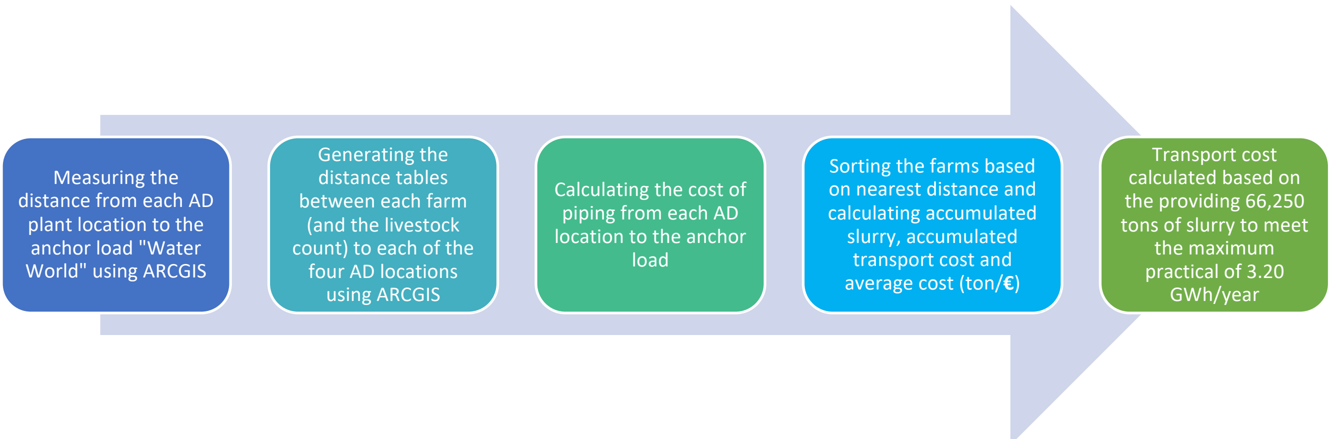


Figure 9-4: Methodology for AD location optimization

The table below compares the results of the optimization process for the AD plant in four possible locations.

Table 9-5: Results of optimization process for the AD in for possible locations

Location	Distance to anchor load (Km)	Piping cost to anchor load: DH (million €)	Piping cost to anchor load: gas pipe (million €)	Average total distance from all farms to AD location (Km)	Average transport cost from farms to AD locations (€/ton)
AD Location 1	1.05	0.423	0.1	38.43	2.22
AD Location 2	3.12	1.24	0.3	28.57	1.72
AD Location 3	6.49	2.59	0.6	21.28	1.38
AD Location 4	9.53	3.81	0.9	17.97	1.25

Compared with AD locations 3 and 4, AD location 1 has the highest average transport cost at least by a factor of 1.2. However, it has the least piping cost by at least a factor of 2 when considering district heating or gas pipe cost. The piping cost will have a very high impact on the investment cost thus AD location 1 seems more attractive in that regard. The below table provides a comparison between all AD locations selection criteria after considering economical optimization.

Table 9-6: final Comparison between all AD locations selection criteria

Location	Close to demand	Close to supply	Regulations considered	Wind direction considered	Impact on investment
AD Location 1	✓	✓	✓	✓	✓
AD Location 2	✗	✗	✓	✗	✗
AD Location 3	✗	✓	✓	✗	✗
AD Location 4	✗	✓	✓	✓	✗

Accordingly, based on the above-mentioned analysis, location 1 has been selected as a possible location for the AD plant. Compared with other locations, it is considered to be matching all set criteria. The graph below shows the average transport cost versus the accumulated slurry for all locations. It can be seen from the graph, that as the demand for slurry increases so does the average transport cost per ton. The optimization has been conducted by covering the demand for slurry from the nearby farms first and as the demand increases more slurry is obtained from the more distant farms. As shown below that, the average transport cost for the maximum tons of slurry (66,250 tons) is around 2.2 Euros per ton for location 1 which is higher compared to other locations. However, for lower demand of slurry, it can be observed that the average cost for AD location 1 is less than the location 2. This is due that the nearest farm to location 1 is 3.32 km away and consists of 800 cattle compared with location 2 which is 6.57 Km and consists of 100 cattle.

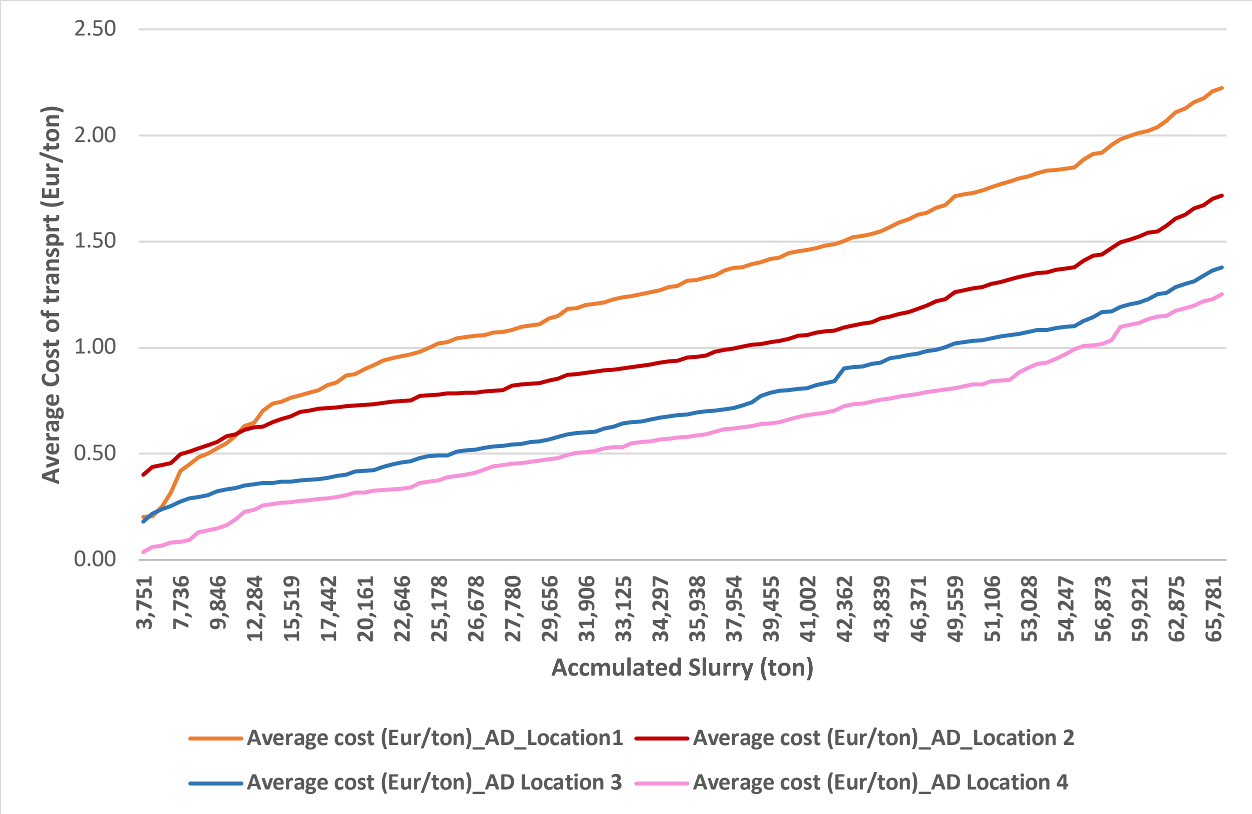


Figure 9-5: Average cost of transport versus accumulated slurry for AD locations (Source: Authors simulation)

9.2 Solar PV on a farm

9.2.1 Geographical location of the site

The orientation of the case study farm is east facing, thus it might be affected by shading as there is a silo adjacent to the building, which will reduce the potential of solar irradiation collected by the PV panels. The meteorological data was downloaded from Meteonorm and uploaded to PVSOL Premium 2020. The plotted weather data on Figure 9-6 shows the chosen farm experiences its highest temperature peak in July and August around 15 degrees ^{0}C. The lowest temperatures are mostly in winter from November to around March. This is important to note if there are high temperatures beyond the Standard test Condition for solar panels which is around 25^{0}c (Homerenergy, 2019). High temperatures may affect PV panels cell efficiency, but lower temperatures may improve the system performance compared to standard conditions.

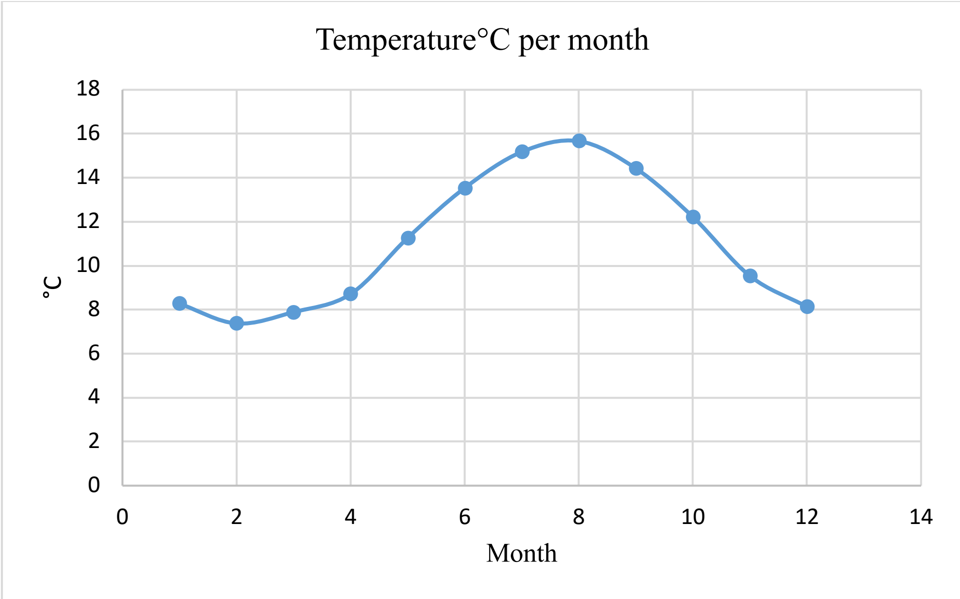


Figure 9-6: Plotted Farm Temperature per month. Data Source: Meteonorm 2020

9.2.2 Daily Load Profile

This section highlights the chosen farm as a basis of the different sizing scenarios with consideration of the daily load profile. The chosen farm for the different measures and technological interventions is a farm with a milking robot, chosen under the criterion of high electricity demand as compared to conventional milking systems. According to (AgriLand, 2019) most traditional family farms have a base load of electricity usage between 2kWh and 6kWh with significant peaks in the morning and evening. In comparison, in dairy farms with robots the base loads are higher. A thorough energy audit was carried out to ascertain the electric farm equipment, considering their use factor which was calculated in relation to the milking process the use factor 0.31 was calculated based on the following assumption taken from interview:

- Total cows milked per day is 75
- Average time for the milking process is 6min

*Use factor = (6*75)/ (60*24) = 0.31*

The total load calculation was based on the formulae P* F_u*Q* H were:

P ~ Power kW

F_u ~ Use Factor

Q~ Quantity

H~ Hours of use

Table 9-7 below summarizes the results inventory.

Table 9-7: Results Summary of Energy Audit Inventory on a Robot Milking Farm. Data Source: Farm Interviews and Observation of Electric Data on the Equipment.

Equipment	Power kW	Use Factor/ Utilisation Coefficient	Quantity	Hours of Operation	Equipment Load
Shed 1, Lights (LED Glass tube T8)	0.017	1	4	12	0.816
Main Shed Lights (LED Glass tube T8)	0.017	1	8	1	0.136
Water Pump	0.75	0.3	2	24	10.8
Activity sensor	0.135	0.3	3	24	2.916
SSg smart gate	0.09	0.3	2	24	1.296
Cameras	0.012	1	4	24	1.152
Pump for drinking Water	1.125	0.3	1	24	8.1
Cow Brush motor	0.06	0.3	2	24	0.864
Computer: CPU and monitor sleep mode	0.06	1	1	24	1.44
Compressor	1.21	0.3	1	24	8.712
Milking robot	20	0.3	1	24	144
Motor meal Blend	0.75	0.3	1	24	5.4

Basic Assumptions considered for this case study state that the base load for a typical day remains the same throughout the year. A typical day load profile was plotted, Figure 9-7 shows the plotted results obtained from the electricity equipment inventory in excel, data sheet shown on Appendix 17.

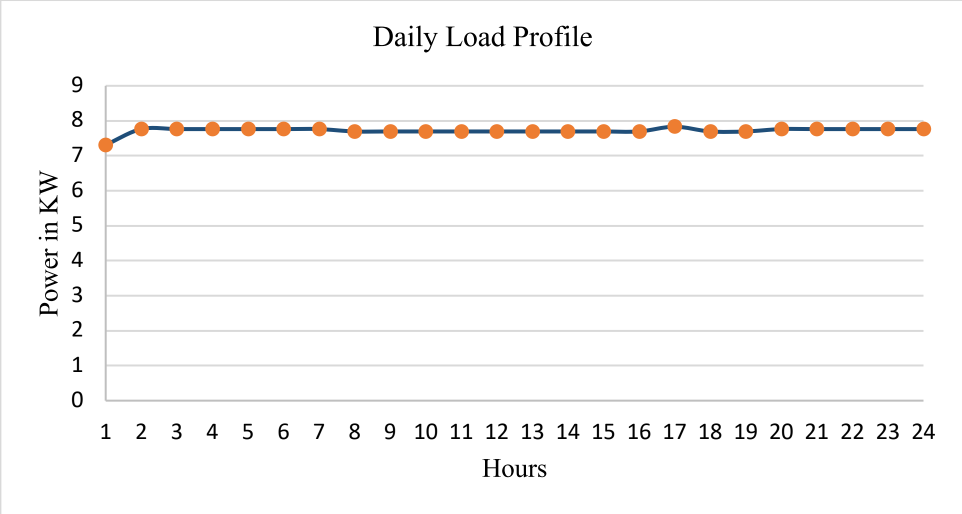


Figure 9-7: Daily Load Profile for the Farm with a Robotic Milker. Data Source: Farm Interview and Observation of Electrical data on Equipment

9.2.3 Methodology for Daily Load Profile simulation PVSOL

The results were loaded in PVSOL Premium where the typical load of 7.641kW was defined. The load profile was loaded under the assumption that the load is constant which is equivalent to an annual energy demand of 66,935 kwh. Figure 9-8 below depicts the results which shows that energy is variable from a month to another because of the number of days in every month however remains within the constant range.

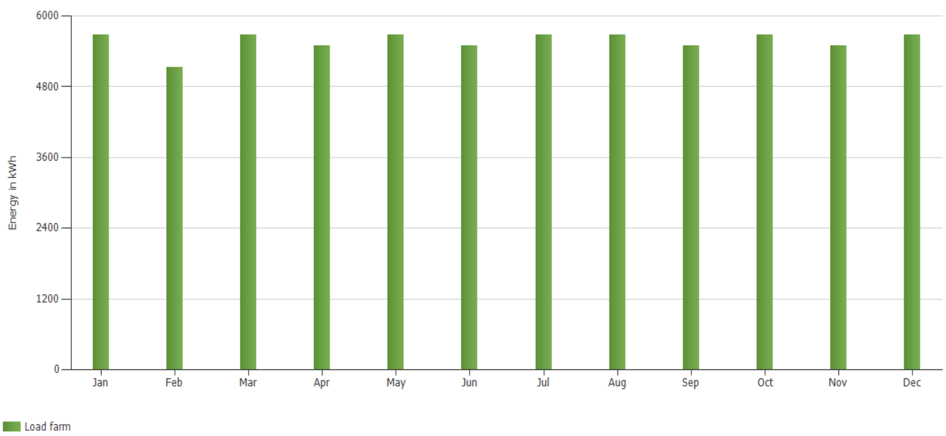


Figure 9-8: Variable Load for Different Months. Source Extrapolated in PVSOL with data from interviews.

9.2.4 System Design

Setup and Description of the Photovoltaic system Scenarios

The proposed scenarios are grid-connected PV systems, which generate electricity for self-consumption and feeding it to the grid in case of surplus. Due to unclear feed-in tariff regulation, the priority here is given for self-consumption. The system is composed of solar panels, inverter, and energy meter and grid connection equipment. The proposed scenarios have effective utilization of power generated from solar energy as there are no electric battery storage losses. When irradiation is high, the photovoltaic system supplies the excess power beyond the consumption of the connected load to the utility grid.

Six scenarios where simulated with consideration of different aspects such as PV capacity, available rooftop area, prices for the equipment of each scenario, shadow avoidance and regulation. The six system designs where include a 5.20kWp, 11.20kWp, 20.50kWp, 40.32kWp, 78.70 and 94.10kWp system. The results were compiled as shown in *Table 9-8*, highlighting major parameters such as the PV generated energy kWh/year, Energy from PV consumed by the load, investment costs, project Internal rate of return and the Levelized cost of Electricity. The highest rate of return, at the lowest generation costs, is achieved by scenario 2. Although it only generates 14% of the electricity needs of the farm, it does so at levelized costs of 11 cents/kWh. As indicated in the table below, Scenario 6 yields the highest PV generated energy output of 78,320 kWh/year, however the majority of the output, 52, 961 kWh has to be fed back into the grid because there is no feed-in tariff for Ireland. Moreover, it has the highest solar fraction feed-in of 63% as compared to other scenarios and the highest investment costs of 108,894 Euros. When the objective is to maximise the solar share while maintaining economic feasibility, scenario 3 has the most feasible results as most of the PV generated can be consumed on farm. This aspect can be considered for making the decision for an appropriate system configuration depending on whether the farmer prefers self-consumption or feeding into the grid. However, feeding into the grid is not commendable under the current lack of feed in tariff. Furthermore, this will be analysed in the financial and economic section based on the LCOE and IRR.

Table 9-8: Scenarios System Design Results Simulation. Data Source: simulation from PVSOL with defined parameters and excel financial model

Scenario Number	PV Output KWp	PV Generated Energy kWh/Year	Energy from PV consumed by Load kWh/Year	Energy from PV Feed-in to the Grid kWh/Year	Solar Fraction consumed by Load	Solar Fraction Feed into the Grid	Investment cost Euros	Project IRR	Project LCOE engineering Euro/kWh
1	5.20	4,123	4123	0	6%	0%	6912	6.80%	0.13
2	11.20	9,349	9,341	8	14%	0%	14,148	8.20%	0.11
3	20.50	17,013	15,030	2,046	22.5%	12%	26,393	6.19%	0.13
4	40.32	33,898	20,791	13,107	31.1%	39%	42,251	-1.02%	0.24
5	78.70	66,066	24,679	41,326	36.9%	63%	93,330	-2.76%	0.28
6	94.10	78,320	25,359	52,961	37.9%	68%	108,894	-4.14%	0.32

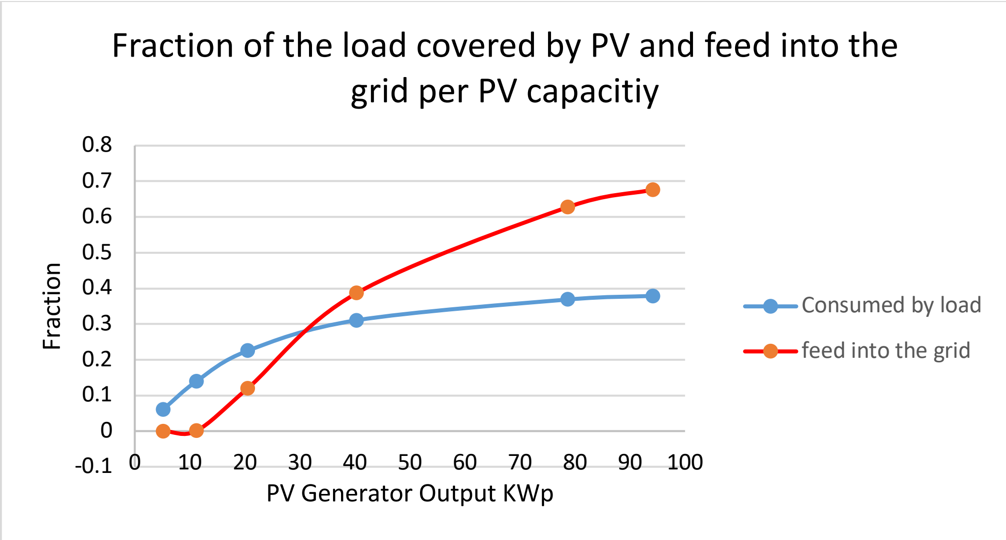


Figure 9-9: Fraction Consumed by the Load and Feed into the Grid per PV Capacity. Source: Financial model Calculations in Excel

Figure 9-9 above illustrates the fraction PV output consumed by the load indicated by the blue curve and the fraction of PV output fed into the Grid indicated by the orange curve. In order to optimise the system, in this case the objective is to:

- Minimise the costs of electricity,
- Maximise the intervention's IRR,
- Maximize the share of renewable energy that covers the load.
- Minimize Electrical output fed into the grid.

The objective is to maximise the blue curve and minimise the orange curve, based on this optimization methodology, the idea is to find a point of equilibrium such as the point of intersection of the two graphs which represent a system around 30kWp. Therefor all the system configurations below 30kWp are technically optimal. This aspect depends on the objective of the system.

The detailed design, simulation and financial model results are found in the Appendices/ Annex section Appendix 17.

9.2.5 Financial and Economic Analysis (Financial Model)

This section highlights the main parameters analysed in the financial and economic model which could be economically relevant for the farmer. This was done to make a comparison and sensitivity analysis of each scenario using different input parameters for Ireland such as:

Operation and maintenance costs set at 1% of total investment.	Inflation costs, 2%	Inflation revenue, 2%
Market risk Premium, 6%	Interest rate of?	Risk Free interest rate, 1.4%

Calculated Weighted Average Cost of Capital, 6.20%	Beta 80%	Tax 0%

NB: For our case the tax was 0 because there was no loan incurred for the investment.

The Beta of 80 % was obtained from (Christian Jaag, 2019). The Beta is a measurement of the systematic risk of the returns for an investment, relative to the market (CFI, 2019).

These input parameters where a basis to calculate the Levelized Cost of Electricity, Internal rate of return, Net present value. Both the technical and economic results will be used as a key element for the decision-making process of the most feasible scenario which is in reference to the summarized results in Table 8-8.

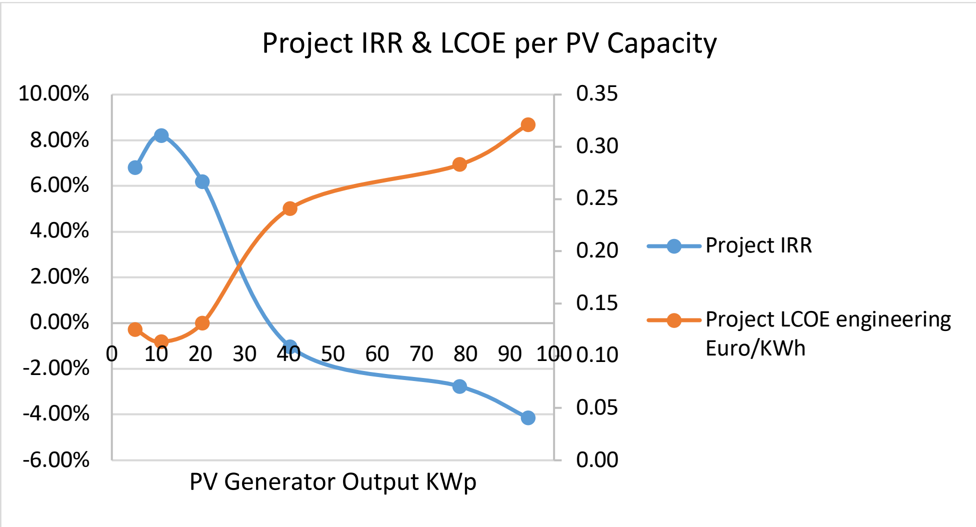


Figure 9-10: Project IRR and LCOE Per PV Capacity. Source: Own Calculations, Financial Model in Excel

Figure 9-10 above depicts the project IRR and LCOE for different Photovoltaic capacity system configuration. Economically and financially, the analysis was set to maximise the project's IRR and minimise the scenarios LCOE. All systems below 30kWp are economically feasible as indicated with the intersection on the two curves. A system around 10kW has the lowest costs of electricity purchase saved and the highest internal rate of return of a modest investment. The financial model in Excel format is presented in the Annex section.

In summary, the technical and economic result of this farm measures and technological interventions concludes that all the systems under 20kWp are technically and economically feasible. It is the decision of the farmer to choose which system is within their economic means and under which objective is important to them.

10 Community Energy

10.1 Overview of Organization Framework and Funding

Organization Framework

The upcoming Renewable Electricity Support Scheme (RESS) has proposed that the community could organize themselves as a co-operative with a minimum of 150 participants with a co-principle of 1 person 1 vote. The community could go for a renewable project having maximum capacity of 5 MW. The co-operative community project needs to have at least 51% of the total shares and the remaining 49% could go to private project developers if they want to be a part of it. Alternatively, the remaining shares could be owned by the community if they have the financing capacity. In addition, a Community Benefit Fund has to be established by the private developer under such an entity and a mandatory fund up to 6 Million Euro per annum has to deposited into it (Western Development Commission, 2019). Residents up to 10km radius of the development site can invest in the project but the priority is given to those within 5km radius (Goverment of Ireland , 2020).

The co-operative, as suggested under RESS, could be "not-for-profit" or "profit based". Communities are allowed to pay dividends to their shareholders if the company model is "for profit co-operative"; however, it is not clear up to how much they can keep if the community go for such model. In addition, it is also not clear if the community-based co-operative will be exempted from taxes under the upcoming RESS scheme or not.

Figure 10-1 shows the proposed framework for enabling the community's participation under RESS programme. As explained above, the community could form a co-operative structure to operate for energy projects and it needs to include Sustainable Energy Community (SEC) network of Ireland. The main idea of partnership with other sustainable energy communities is to exchange ideas and get help in preparing an energy master plan. The plan could include pathways for the transition to renewable energy and other low carbon energy infrastructures such as district heating grids. The government will provide financial, intermediary and advisory support on the energy master plan of the community financially. They will provide Trusted Intermediaries as Mentors to support communities for co-ordinating activities across a wide range of public and private sector organizations, and Trusted Advisors for providing technical expertise (Western Development Commission, 2019).

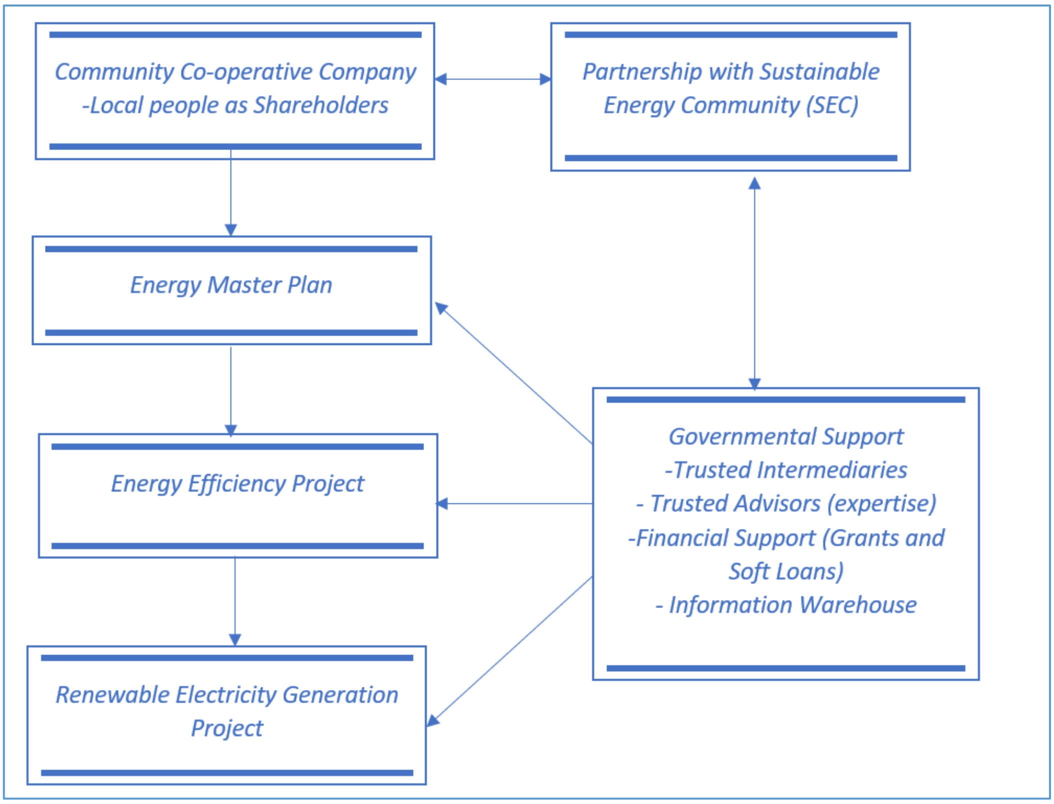


Figure 10-1: Chart Showing the Community's Journey Under Community Enabling Framework (Source: Author's Elaboration using data from (Western Development Commission, 2019))

Existing Communities as Examples

"In Europe, the term "Community energy project" refers to projects where citizens own or participate in the generation of sustainable energy (Climatepolicyinfohub)." Denmark and Germany are considered as the pioneer for community energy projects. They present themselves as an example for the success of the renewable energy projects when communities are involved. They have been showcasing economic, social and environmental benefits that community energy projects come along with. 83 MW Windfarm in Germany owned by 360 families from three surrounding villages is one of the excellent examples of community owned energy project. Shares were available from 5,000 Euro for that project and about 25 Million Euro were collected from the local shareholders, and the remaining 100 Million Euro was financed by loans from 14 banks (Wind-Kraft, 2014). Community energy is a nascent sector in Ireland; however, there are already examples in Ireland where community energy projects have become successful. The following three most recognized existing community projects in Ireland could be examples to the community in Loop Head to plan for future community owned projects.

Templederry Wind Farm

Templederry wind farm is the first community owned energy project in Ireland. This wind farm is in a small village in the Selive Felim Mountains in Tipperary in Ireland. It consists of two turbines each 2.3 MW and produces approximately 15GWh per year and is powering approximately 3000 homes. The project was developed with the cost of 6.2 Million Euro and is expected to return 1.2 Million Euro in a year to investors and local community before debt service, operation and other costs (TipperaryEnergyAgency).

The planning for the project in 2003 was started with the support of 29 locals contributing 1000 Euro per person. This project has total 30 shares with 27 shareholders are residents, 1 free share for Tipperary Energy Agency, TEA and 2 free shares for Community Co-op. This farm was then financed by the shareholder's equity, LEADER grant funding, business expansion loan from the turbine manufacturer "Enercon", and the loan for the project was financed from the De Lage Landen, a subsidiary of Rabobank (Independent.ie, 2014). 71% of the debt financing was from De Lage Landen, 25% equity was financed by the shareholders, and the remaining by the grants and business expansion loan and mentioned earlier (Slideshare, 2015).

Arran Island Energy Co-op

The co-operative was set up in 2012 as a non-profit organization which is focussing on energy efficiency and renewable energy. The main objective of the organization is to facilitate an energy transition by 2022. Comharchumann Fuinnimh Oileáin Árainn Teoranta (CFOAT) is the name of the co-operative where only residents and business located in Aran Islands can become full members with voting rights. With the purchase of shares of 100 Euro each, lifetime membership can be formed. This co-operative has a board of 12 elected members with an AGM in each year. Currently, there are 85 members in this co-operative (AranIslandEnergy).

CFOAT is engaged with Warmer Homes Scheme, Better Energy Community Scheme, and Greener Homes Scheme under SEAI for upgrading residential, private and public buildings and businesses on the islands. The co-op has also gained the success on the pilot project of electric vehicle. The island has 10 privately owned electric vehicles and 8 electric bikes until now. In addition, the co-op is involved in research and development projects like hydrogen production from renewable energy, smart homes, geothermal energy schemes and micro-grid (AranIslands, 2018).

Claremorris and Western District Energy Co-op

This co-op was founded in 2015 by the people of Claremorris in Ireland for developing community owned renewable energy projects, supporting communities and addressing climate change. There are over 50 members in this co-op, which are voluntarily engaged for supporting the Claremorris community and others for the transition into low carbon economy (Sparkchange, 2018). This co-op is working with SEAI, Mayo County Council, Clan Credo, Tipperary Energy Agency and others together with the community.

This co-op has 7 locals as shareholders with the experience in community energy development, business and energy sector. Gas networks Ireland and Mayo County Council are important stakeholders since they supported the co-op financially. They are working on the trailer-based AD Biogas demonstration plant with the support of 60,000 Euro from Gas Networks Ireland. 100,000 Euro has been spent on this project from the initial inception of the project (this cost excludes costs taken on personally by the co-op members) (GREBE, 2017).

Funding opportunities:

Funding is considered one of the main challenges facing community owned projects. Through the course work of this research, serval entities have been contacted such as "Community finance Ireland, "ClanCrado "and "WDC" to inquire regarding possible financing for renewable energy generation projects for different technologies, the below table summarizes the possible finance services offered from these entities.

Table 10-1: Funding options (Data source: Organizations contacted by Authors)

Community finance Ireland	ClanCardo	WDC

• **Type of finance:** Loan
• **Interest rate:** 3%
• **Duration**: 15years
• **Maximum Funding**: 500,000 Euro
• **Pre-set conditions:**
  • Community group are associated with DCCAE
  • Completed a pre-feasibility study
  • High share of equity of or remaining finance secured to cover the remaining balance
  • Contact with community power
	• **Type of finance:** Loan or bridge financing
	• **Interest rate:**
	  • Loan_4.95%
	  • Bridging loan:6%
	• **Duration**: Loan 15 years
	• **Maximum Funding:**
	  • Loan: 500,000 Euro
	  • Bridging Loan:1 milion
	• **Pre-set conditions:**
	  • Loans provided to non-profit cooperatives and companies limited by guarantees
	  • Profits to be re-invested in the community
	  • Proof of income for loan repayments
	  • Security against loan such as a charge on site
		• **Type of finance:** Loan
		• **Interest rate:** 3%
		• **Duration**: Not disclosed
		• **Maximum Funding:**
		  • Not disclosed
		• **Pre-set conditions:**
		  • Not disclosed

These loans can contribute to the investment; however, they only represent around 9% of the upfront costs required for renewable projects. Which means that, large share of financing needs to be secured by the community through alternative sources or maybe another loan with a different interest which could range from 4.56% (IWEA , 2019). This makes the loan expensive and may negatively impact the project. Additional funding possibilities are illustrated in the below figure. These entities have not been contacted; however, they represent a good possibility for the financing of feasibility studies and projects.

Feasbility studies funding

- SEC(Sustainable energy community program) (LECO , 2019)
- "LEADER Programme 2014-2020 (pobal, n.d.)
- Through RESS scheme even though not yet announced (LECO , 2019).

EU grants

- **EU grants can be accessed via the local representatives such as**:
  - "The Wheel " (Sandra Velthuis, 2016)
  - " Leader- Rural Ireland" (Rural Ireland , 2020) : Supported funding of Templederry wind Farm

Financing institute

- **De Lage Landen (a subsidiary of Rabobank finance group):**
  - offers loans based on cooperative principles (Rabobank Group, 2019)and it was also involved in the financing of Templederry wind Farm as illustrated above.

Figure 10-2: Possible entities for funding for different stages of the project

Partnerships

The following partnerships are suggested to further enhance and complement the community owned projects.

Community Power: Is qualified as a large supplier to the national grid and thus are enabled to sell electricity to grid. Established by Templederry wind frame, Community Power offers the possibility of purchasing the renewable energy generation from a community, selling it on their behalf to the grid through a PPA (power purchase agreement) (Community power, 2019)

Limerick Institute of Technology (LIT): LIT offers tailor made courses for the general public. The minimum number of participants ranges from 10 -12 per course. The total duration of the course is based on the content. Training is recommended to enhance the know-how and general knowledge of the community. This will facilitate the successful execution of a community owned project

Templederry Wind Farm and Arran Islands Energy Co-op: As these already are existing community owned groups, partnership is recommended to facilitate the exchange of knowledge and expertise.

10.2 Energy Efficiency in Buildings

Ireland aims at a 20% improvement in the energy efficiency by 2020 which represents primary energy savings of 31,925 GWh (DCCAE, National Renewable Energy Efficiency Action Plan), however, it is likely that this target will be missed with the achievement to be around 16% (SEAI, National Energy Projection to 2030, 2018). To achieve this target, the Department of Communications, Climate Actions and Environment together with Sustainable Energy Authority Ireland (SEAI) and other state bodies are implementing policies on energy efficiency. SEAI is administrating energy efficiency programmes for domestic, public and commercial sectors considering energy efficiency as the important part of Ireland's transition to low carbon energy future. Better Energy Homes, Building Energy Rating Scheme, Better Warmer Homes, Better Energy Communities, etc are the programmes administered by SEAI for homeowners, public, communities, businessman, etc, for improving energy efficiency by providing support through grants, incentives and trainings.

Existing Policy

As mentioned in Section 7.3.2, the "Better Energy Communities" programme is an integral part of the national retrofit initiative in Ireland to support the energy transition of the country. Since the programme encourages partnerships in this scheme, it can include partners from the public and private sectors, residential and non-residential sectors commercial and not-for-profit organizations and energy suppliers (DCCAE, National Energy Efficiency Action Plan 2017-2020, 2017). Table 10-2 shows the available community grant scheme (SEAI, SEAI Community Energy Grant 2020 Application Guidelines, 2020)].

Table 10-2 Communities Energy Grant 2020 (SEAI, SEAI Community Energy Grant 2020 Application Guidelines, 2020)

Community Grant Scheme	
Residential Sector	
Maximum number of Households	250
Funding for Private Non-Energy Poor Residential Homes	35%
Funding for Private Energy Poor Residential Homes	80%
Funding for Residential Local Authority Homes	35%
Funding for Housing Association Homes	50%
Non- Residential Sector	
Funding for not-for-profit/ community	50%
Private and Public Sector	30%
Public Sector	30% to 50%
EV Charging Points	30%

The maximum grant available in the Communities energy grant is 1,500,000 Euro. It has no maximum project value and it is recommended that the grant applications of at least 50,000 Euro is made. The maximum percentage of funding available for the overall scheme is 50%. And, even if an application consists of varying funding rates between 30% to 80% in overall for the project; only 50% as maximum grant will be available. In addition to available maximum grant, some applicants may be considered for additional augmented grant if they apply for less than 200,000 Euro, are registered SEC and they are applying for first or second time [(SEAI, SEAI Community Energy Grant 2020 Application Guidelines, 2020)].

Categories which are eligible for the grant are as shown in Figure 10-3. It is recommended that all the applicants should try to include more than one from latter mentioned categories [(SEAI, SEAI Community Energy Grant 2020 Application Guidelines, 2020)].

Figure 10-3 Different categories for Community Energy Grant

(Sources: Author's Elaboration using data source (SEAI, SEAI Community Energy Grant 2020 Application Guidelines, 2020))

An example of a Community Energy Efficiency Grant for Kilkee for Roof and Wall Insulation

An example on how beneficial community energy efficiency grant will be when different sectors in the community partner together for upgrading their buildings has been analysed. In Kilkee, 68 occupied houses built prior to 1919 are chosen for the study. Those buildings are assumed to have a BER of G, considering houses built prior to 1929 on average have a BER rating of G (TABULA, 2017). The main idea of conducting this study is to provide a general overview about the cost and benefits if different sectors in a community partner together for the building retrofit.

Most of the residential building stock, built prior to 1929 is assumed to be Bungalow, Solid Brick or Stone Walls (TABULA, 2017). Average standard upgrading costs are estimated as shown in Appendix 14.

To analyse the benefits of community energy efficiency grant scheme, following three scenarios are considered:

1. Scenario 1: "Residential Non-energy Poor Partnerships for Retrofit"- When only private non-energy poor residential buildings' partner together for community energy efficiency scheme

2. Scenario 2: "Residential Non-energy/energy poor and Non-residential Partnerships for Retrofit"- When residential buildings partner with non-residential not-for-profit buildings, or with private energy poor residential buildings for community energy efficiency scheme

3. Scenario 3: "Individual Building Retrofit"- When individual building goes for building upgrading without any partnerships

A simplified comparison in terms of average financial costs savings and primary energy savings is presented in Table 10-3. Grants for individual building retrofit from SEAI has been attached in Appendix **15** (SEAI, SEAI Community Energy Grant 2020 Application Guidelines, 2020). Calculations are based on average costs for building upgrading taken from TABULA (TABULA, 2017) and are performed without considering fees required for assessing BER, consultation fees and other fees associated with administration. At least 3 buildings under the above mentioned scenarios need to participate for receiving grant as mentioned in the existing policy that the minimum value of one upgrading project needs to be 50,000 Euro.

Table 10-3 Cost Saving Analysis considering different scenarios for community energy efficiency (Source: Author's Calculation)

S.N.	Scenario 1	Scenario 2	Scenario 3
Total number of participants	68	68	68
Average costs per household required for upgrading Roof and Wall	€ 18,693	€ 18,693	€ 18,693
Total average project costs for Roof and Wall upgrading	€ 1,271,124	€ 1,271,124	€ 1,271,124
	35% of the total project cost	50% of the total project cost	€ 6400 (for roof and wall insulation)

Available SEAI Grants	= € 444,893	= € 635,562	= € 435,200
Total required costs after receiving grants	€ 826,231	€ 635,562	€ 835,924
Costs required for upgrading one household after deducting grant	€ 12,150	€ 9346	€ 12,293

Table 10-3 shows the savings in costs from grants if house owners in a community partner with other private non-residential not-for-profit building owners or private owners of energy poor compared to the savings of individual households go for building retrofit alone. Around 15% of the total amount required for wall and roof upgrading could be saved if residential energy poor or non-energy poor and non-residential not-for-profit buildings partner together, given the buildings are eligible for grants. In addition, there will be savings in terms of primary energy and corresponding saving in the fuel price for heating for this house typology. Total savings in heating oil per household is estimated to be 1395 Litres/year/household and detailed calculation has been attached in

Appendix 16.

This community energy efficiency not only brings savings in costs and fuel, but also possible partnerships formation that could be helpful to implement other sustainable community energy related projects in Loop Head.

10.3 Wind

A third turbine Enercon E 70, 2.3 MW with the same technical characteristics has been added on the existing "Carrownaweelaun Wind Farm" to give an overview to the community about its techno-economic and environmental feasibility in terms of annual energy generation, investment costs, internal rate of return (IRR), payback period and its environmental impacts like noise and shadow flicker.

Wind Statistics

This new turbine has been simulated with a hub height of 59 meter, like the existing wind turbines in the farm in Loop Head. Since, the wind turbine in existing wind farm in Loop Head is at 59 meter hub height, it is important to look on wind statistics (wind speed distribution and its frequency of occurrence) at this hub height. The free mean wind speed, that means the wind speed at its natural velocity being uninfluenced by the turbines in the wind farm, is around 7.5 m/s at hub height of 59 meter as shown in Figure 10-4 with frequently occurring wind speed from West-South-West (WSW) direction. The energy rose diagram in Figure 10-4 shows that the maximum energy production will be in WSW direction as the wind is blowing 17.5% of the total time from WSW direction. Around 8% of the uncertainty in the wind speed is observed as both the data used for correlation are not actual measured data with wind mast in wind farm in Loop Head.

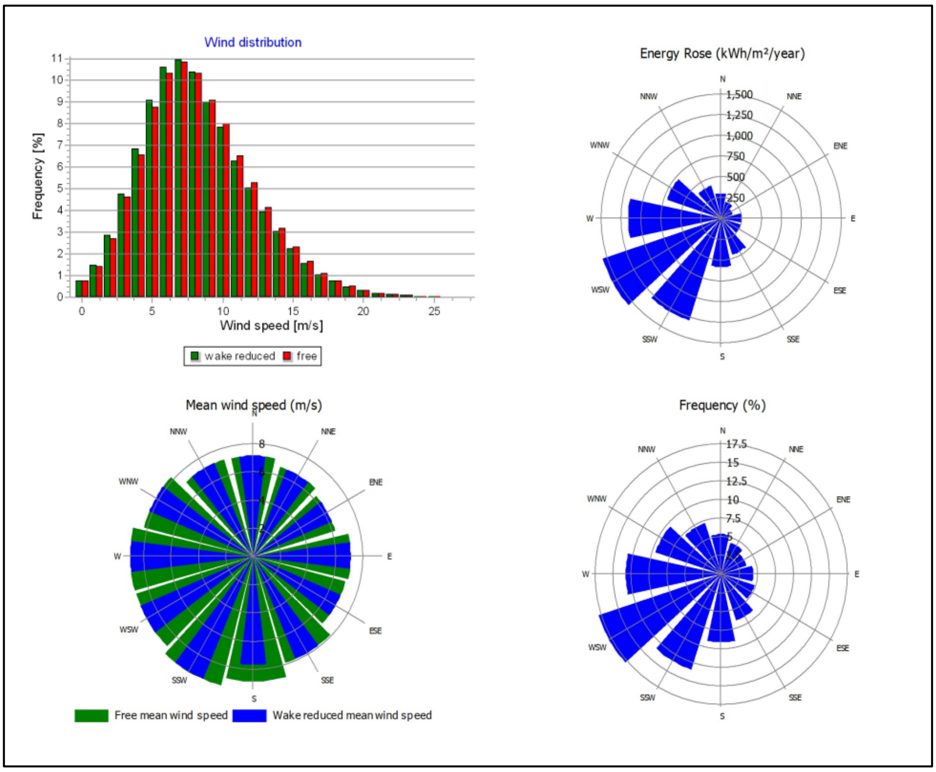


Figure 10-4: Wind Statistics at the Hub Height of 59m

(Source: Author's Calculation Using WindPro, Data Source: (EMD))

Annual Energy Output

According to the simulation in WindPRO, the annual energy production is 6,625 MWh/year with the capacity factor of 32.9% and detailed result on it is added on Appendix 11. The power production is higher during winter than in summer as shown in Figure 10-5.

Figure 10-6 shows the annual energy production is higher in WSW direction out of 12 different directions. Wake loss is observed due to the impact of the wind turbines on each other, causing reduction in wind speeds.

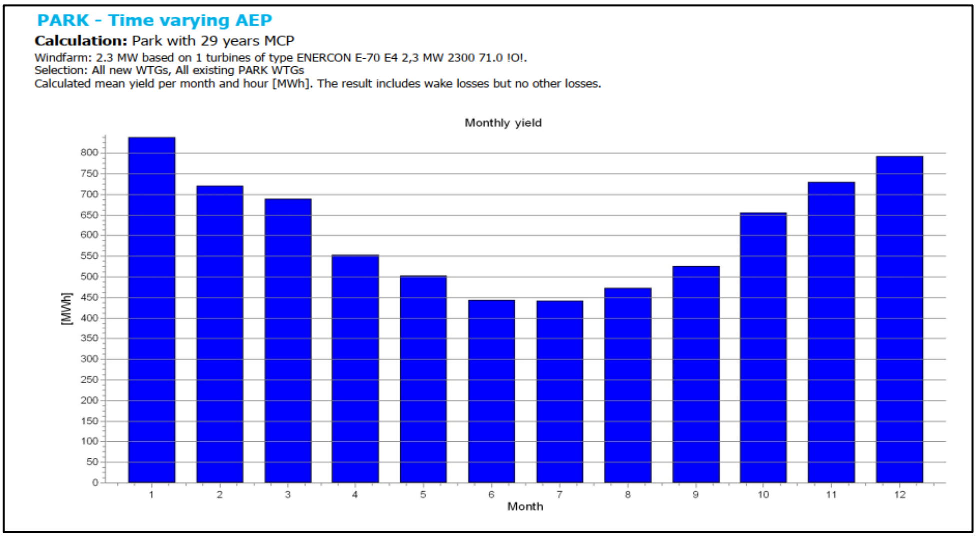


Figure 10-5: Monthly Energy Production from a new third turbine showing seasonal variation (Source: Author's calculation using WindPro, Data Source: (EMD))

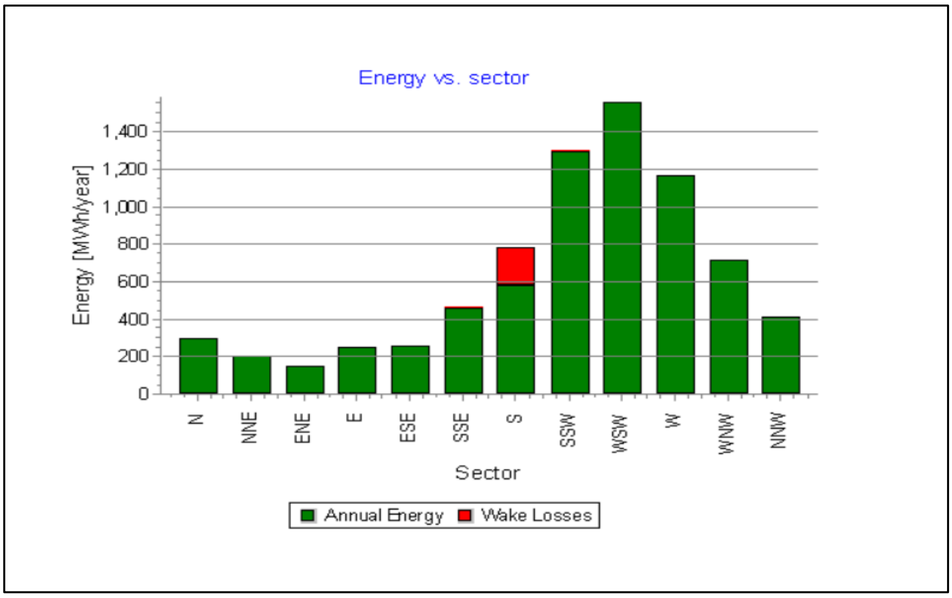


Figure 10-6: Annual Energy Generation and wake losses in different directions (Source: Author's calculation using WindPro, Data Source: (EMD)

Environmental Impact

Noise and shadow flicker are calculated to help deciding whether it will be appropriate to build a new turbine or not.

i. Noise Impact

The audible frequency of sound for the human ear is from 20Hz to 20 kHz and human hearing ranges from approximately 0 dB (threshold of hearing) to 120 dB (threshold of pain) (GreenFacts, 2020) (MiniPhysics, 2015). Noise is a non-desirable sound that is experienced by the listener and its effects could be subjective.

Noise calculation has been done with the available model ISO 9613-2 General 8 m/s on WindPRO. Figure 10-7 shows the location of the building that could be subjected to noise impact.

Figure 10-7: Noise Sensitive Areas as shown in Google Map

(Source: Author's calculation using WindPro, Data Source: (EMD))

Table 10-4 below shows the noise sensitive areas and the distances measured from the existing and a new wind turbine referring to Figure 10-7.

Table 10-4: Nearest Noise Sensitive Areas as Observed from Google Map

S.N.	Nearest Sensitive Areas from Wind Turbines	Distance (m)
1.	From New Wind Turbine, WT to Noise Sensitive Point 12	720
2.	From New Wind Turbine, WT to Noise Sensitive Point 5	577
3.	From New Wind Turbine, WT to Noise Sensitive Point 6	541
4.	From Wind Turbine, W1 to Noise Sensitive Point 7	490
5.	From Wind Turbine, W1 to Noise Sensitive Point 8	457
6.	From Wind Turbine, W2 to Noise Sensitive Point 8	428
7.	From Wind Turbine, W2 to Noise Sensitive Point 11	470

The minimum audible noise is found to be 39 dB and the maximum is of 41.8 dB emitted from all of three wind turbines in a farm. Figure 10-8 shows the map with different noise levels in noise sensitive areas around wind farm. The detailed result on it is attached on Appendix 12.

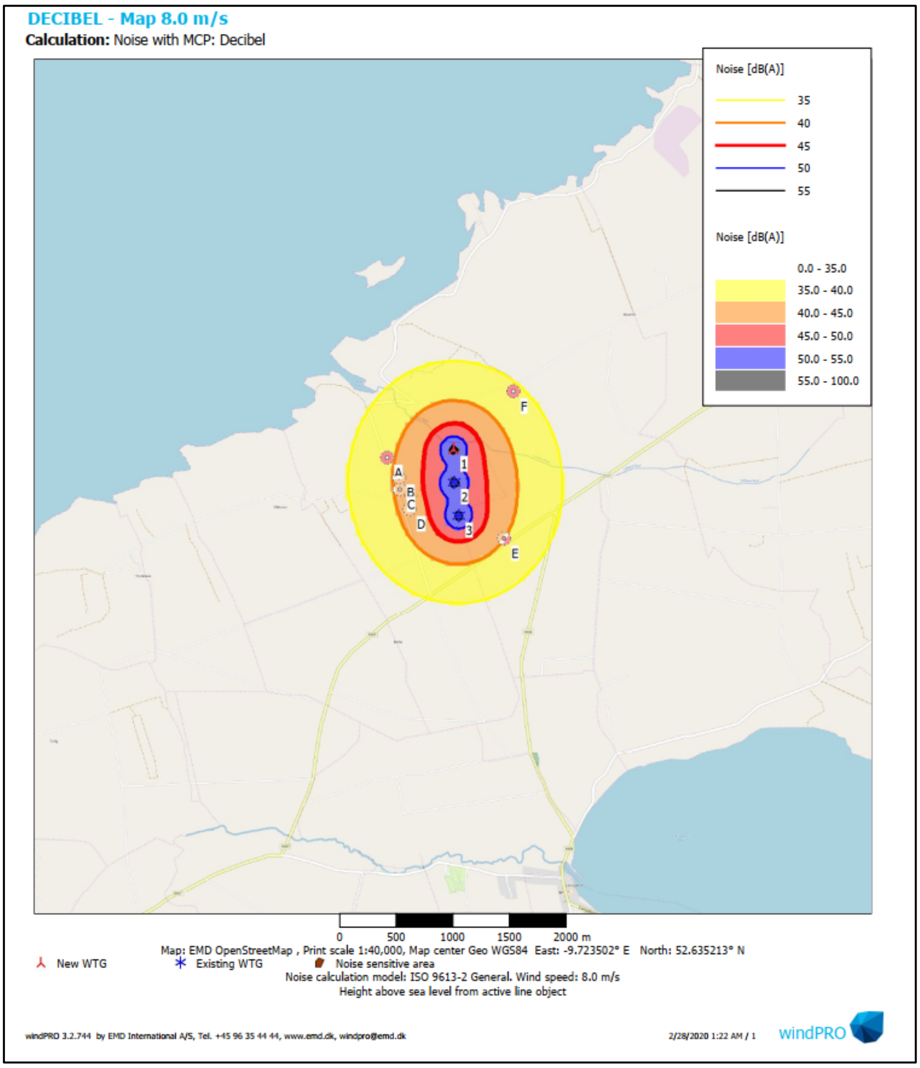


Figure 10-8:Noise Level in 6 Noise Sensitive Areas

(Source: Author's calculation using WindPro, Data Source: (EMD)

Ireland has proposed noise limits aligning with the World Health Organization (WHO) guidelines, proposing a relative noise limit of 5 dB (A) above existing background noise within the range of 35 to 43 dB (A), with 43 dB (A) being the maximum noise limit permitted on day or night. This noise limit applies to outdoor locations at any residential or noise sensitive properties (Ireland, Wind Energy Development Guidelines, 2019). From the calculations and the proposed regulation in Ireland, the noise level from the simulated wind turbines in a wind farm in Loop Head is within the limit but seems to be critical.

ii. Shadow Flicker

Shadow flicker occurs when the light escapes through the gaps between the blades of the turbine from the light that is shining behind them. It is caused by the shadows that are given off by the wind turbines when they are in full rotating motion (discoverwindenergy, 2020). Shadow calculation assumes that the sun is shining all day from sunrise to sunset, that the rotor plane is always perpendicular to the line from the wind turbine generator to the Sun, and the wind turbines are always operating.

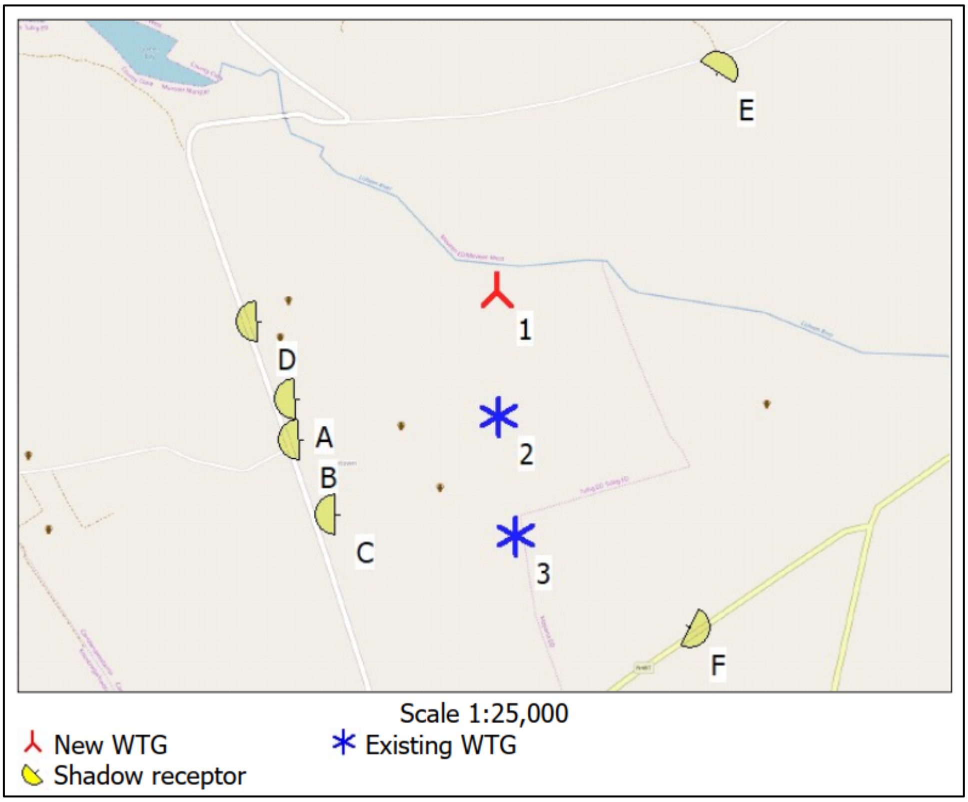


Figure 10-9: Nearest Shadow Receptors (A, B, C, D, E and F) from Three Wind Turbines (Source: Own calculation using WindPro, Data Source: (EMD)

Calculation Results

Shadow receptor

	Shadow, worst case		
No.	Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]
A	57:16	169	0:34
B	34:16	121	0:34
C	59:17	124	0:39
D	27:57	107	0:27
E	13:07	64	0:22
F	44:36	81	0:38

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]
1	ENERCON E-70 E4 2,3 MW 2300 71.0 !O! hub: 59.0 m (TOT: 94.5 m) (8)	58:09
2	ENERCON E-70 E4 2,3 MW 2300 71.0 !O! hub: 59.0 m (TOT: 94.5 m) (11)	79:22
3	ENERCON E-70 E4 2,3 MW 2300 71.0 !O! hub: 59.0 m (TOT: 94.5 m) (12)	98:58

Figure 10-10 Maximum Shadow Flicker to be experienced by 4 Shadow Receptors

(Source: Author's calculation using WindPro, Data Source: (EMD)

Figure 10-10 shows that the new turbine "**ENERCON E-70 2.3 MW 2300 71.0 !O! hub: 59.0 m (TOT: 94.5 m) (8)**" is flickering shadow of 58:09 hours/year.. Figure 10-11 shows the shadow flicker map observed in a whole year nearby wind farm area. Shadow flicker on the four receptors (A, B, C, and D) has been observed to be happening around 7:30 am to 9:30 am during winter season when the Sun is low in the sky and, when the Sun is high in the sky during summer time, shadow flicker on those receptors is observed to be happening around 5:45 am until 6:30 am. And, shadow flicker on receptors E is observed to be in December and January from 3:30 PM to 4:30 PM, and receptor F has experienced shadow flicker during summer from May to August from 8:30 PM to 9 PM as shown in Appendix 13. Shadow flicker could be eliminated if the wind turbine operator would be able to shut down the turbine for the period when there is occurrence of shadow flicker.

Figure 10-11 Shadow Map observed over a year

(Source: Author's calculation using WindPro, Map Source: (EMD)

Cost Benefit Analysis

The upcoming RESS scheme in Ireland includes an opportunity proposed for the community to be organized in a Co-operative structure for community energy projects. So, considering this proposition, if the community would like to go for the community owned projects then they could choose co-operative for profit or not-for-profit with shareholders from the community as mentioned in section 10.1. The internal rate of return for community members and the payback period have been analysed to see if the investment would bring return or not.

The technical parameters of the turbine and its annual energy output are shown in Table 10-5and the assumed investment costs for the technology are shown in Table 10-5. The investment cost per kW for onshore wind farm in Ireland from 2016 data is assumed to be 1677 Euro/kW including grid connection costs (IEAWind, 2018). However, based on average grid connection costs in Germany (IWES, n.d.) , the grid connect cost has been reduced from this investment cost by 5% as the existing wind farm is already connected to the grid (IWES, n.d.) . Debt and equity are assumed to be 80% and 20% respectively. Project financing cost is assumed to be 4.56% (IEAWind, 2018).

Table 10-5 Technical Parameters of the Wind Turbine

Technical Parameters		
Turbine:	Enercon E-70	Units
Rotor Diameter	71	M
Rated Capacity of Turbine	2.3	MW
Hub Height	59	M
Number of Turbines	1	
Capacity Factor	32.5	%

Full Load Hours	2880	Hours
Average Annual Energy production (including 10% reduction for Bank)	6625.10	MWh/year
Project Life Cycle	20	Years

Table 10-6 Financial Parameters for the Wind Energy Generation

Financial Parameters		
Investment Costs	1593.15	EUR/kW
Total Investment Costs for 2.3 MW Capacity	3664	'1.000 EUR
O&M cost	34	EUR/kW
Total O&M Cost for 2.3 MW Capacity	78.2	'1.000 EUR/Year
Debt	80	%
Equity	20	%
Interest Rate	4.56	%
Discount Rate	5.07	%

As mentioned in Section 7.3.1, the new RESS is going to be legislated with different schemes for different sizes of wind power plants. Since there is no current information regarding the power prices in coming years under RESS scheme, the power prices has been taken from REFIT as shown in Figure 10-12 (Ireland, Reference Prices for REFIT Schemes, 2020).

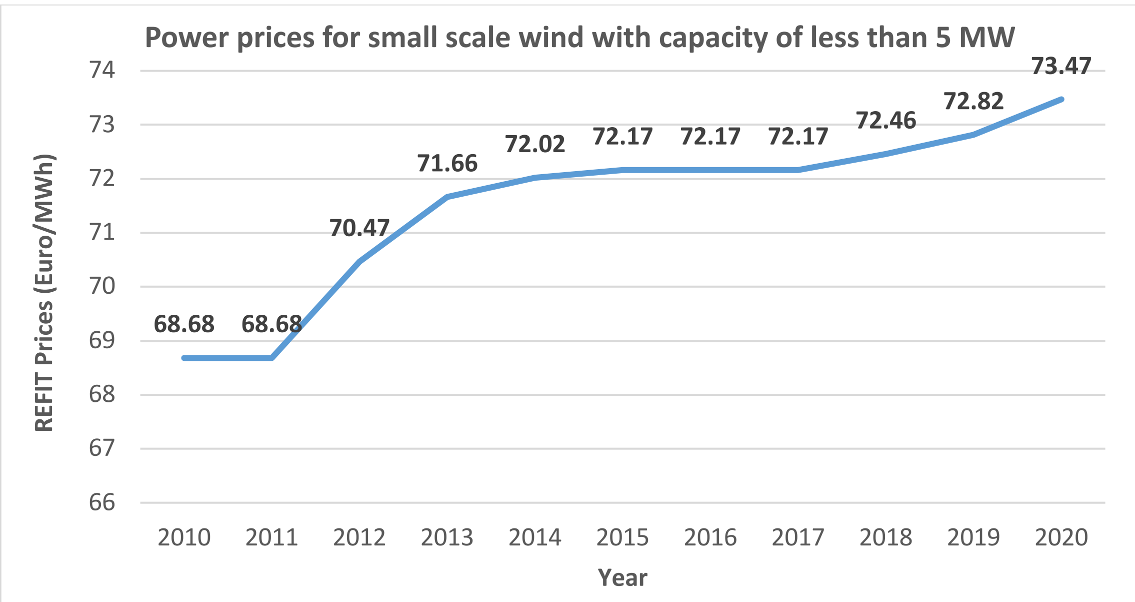


Figure 10-12 REFIT Power prices for Small Scale Wind Farm in Ireland (less than 5 MW)

Two scenarios are analysed taking power prices based on Figure 10-12.

Scenario 1 is considering the lowest power price of 68 Euro/MWh observed in a decade for calculation and Scenario 2 is considering the power price of 73.47 Euro/MWh observed in a decade for calculation.

Since REFIT 2 prices are valid for 15 years when project starts to generate electricity, the minimum power price for the remaining year is assumed to 60 Euro/MWh (Author's Assumption for the worst case scenario).

Different market rates (inflation, risk free rate) of Ireland have been taken into consideration for calculating IRR and payback period for the investment. Calculation results is summarized in Table 10-7Table 10-7.

Table 10-7 Financial Results of the Investment on a Wind Energy Generation at the Hub Height of 59m in Loop Head (Source: Author's Calculation)

S.N.	Scenario 1	Scenario 2
1. Annual Energy Generation (MWh/Year) at the hub height of 59m	6,625	6,625
2. LCOE (Euro/MWh)	57.73	57.73
3. NPV (Euro)	308,070	648,490
4. IRR Project	6.13%	7.29%
5. IRR Shareholders	8.16%	11.77%
6. Payback Period	17 years	15 years

For the IRR as shown in Table 10-7 to be obtained, the minimum power price needs to be **18% to 27%** more than the LCOE. However, since the power prices under new RESS is not confirmed, the sensitivity of power prices is analysed in Figure 10-13 in order to know what the minimal margin on LCOE could be. It shows that the minimum margin on the LCOE should be at least 11% as the project starts to become viable at power price of 64 Euro/MWh. However, for the investment to be attractive, power price should be greater than 64 Euro/MWh as illustrated below in Figure 10-13.

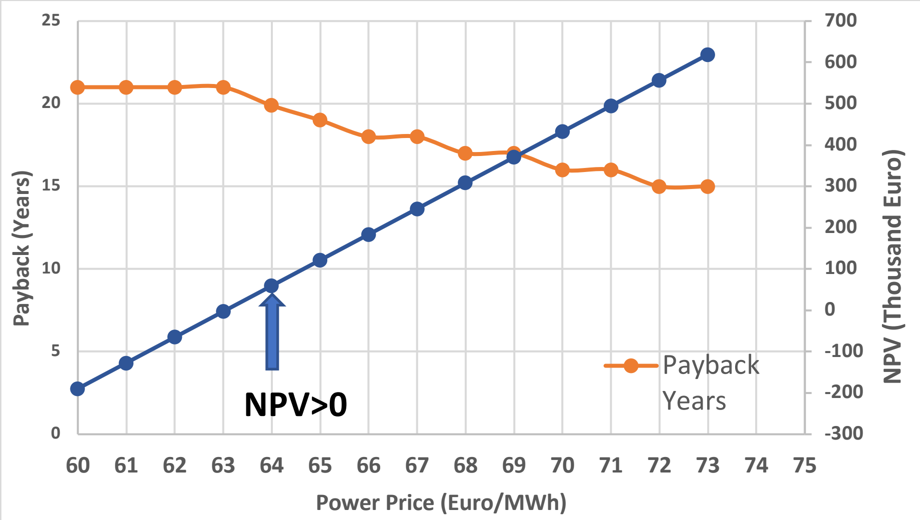


Figure 10-13 Sensitivity of Power Prices on NPV and Payback Period

(Source: Author's Calculation)

Assuming that the investment would be attractive at IRR of 7%, the power price required would be 73.473 Euro/MWh. And, the cash flow after debt services is shown in Figure 10-14.

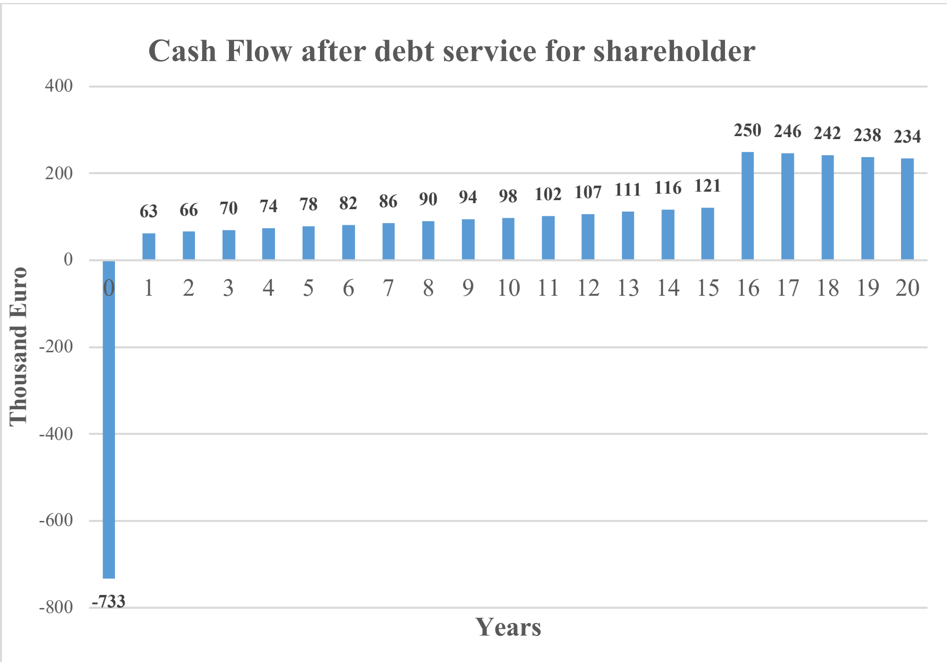


Figure 10-14 Cashflow after debt service for 2.3 MW Wind Energy Generation

(Source: Author's Calculation)

Assuming that the co-operative company for this community wind energy project has a minimum of 150 shareholders with 1 shareholder owning at least 1 share of the company (as proposed by RESS (Western Development Commission, 2019)), each shareholder would receive 418 Euro as minimum and maximum of 1665 Euro after loan repayment and is illustrated in Figure 10-15.

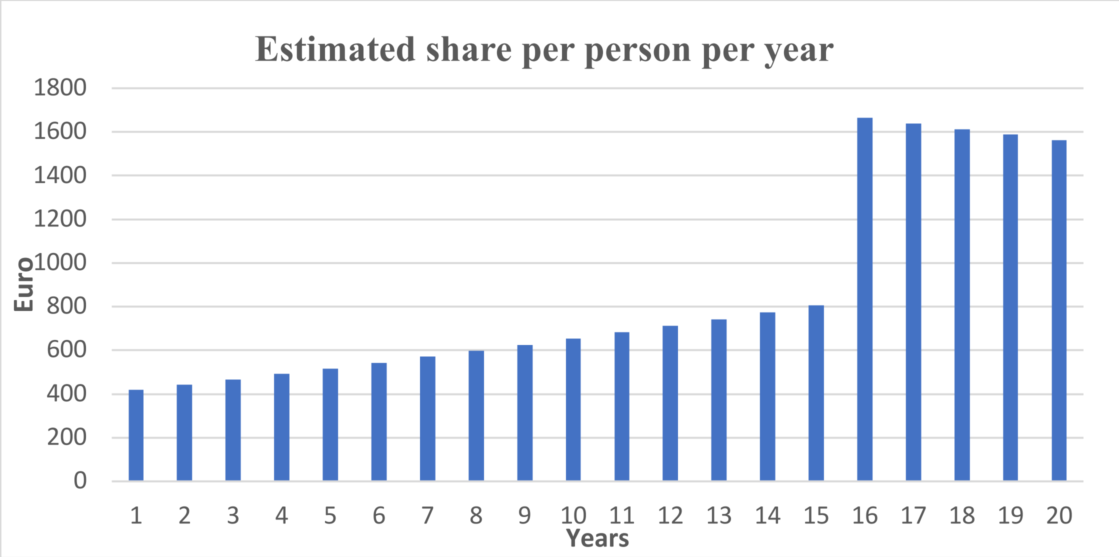


Figure 10-15 Estimated share per person per year with total of 150 participants

(Source: Author's Calculation)

Possible Contribution of the Wind Energy Generation to the Energy Balance of Loop Head

The total annual energy demand in Loop Head is around 75.23 GWh and the annual generation from a 2.3 MW of Wind Turbine is calculated to be around 6.63 GWh. This generation could contribute 9% to the total energy demand in Loop Head. And, this generation from the wind turbine is likely to cover around 35% of the total electricity demand of around 18 GWh of Loop Head (Source: Author's Calculation).

10.4 Solar

In this section an overview regarding community owned solar project will be presented. Starting with a technical analysis, followed by a brief overview of the current market and preliminary investment.

Technical overview: Solar Resource Assessment and Energy Yield Estimation

For a multi-megawatt scale community solar PV project, a reference site of 5 MW capacity was simulated using "PV*SOL®" software. This software is widely used in industry for planning and development of PV projects. The weather data used for resource assessment is available from the METEONORM database software for the Kilkee region.

Based on the results generated by the simulation, the annual irradiation at an optimally tilted surface of modules is 1104 kWh/m^2 and the total energy yield estimation is 5.02 GWh/a by installing a capacity of 5MWp of PV modules. As irradiance does not change a lot by small changes in location (see section 5.1), the same performance can be expected in nearby areas. Based on the seasons, monthly generation is different and follows a specific distribution. The temperature also plays a vital role in performance of PV modules and inverters. The monthly distribution of energy generation and average monthly irradiation are shown in Figure 10-16. Further details about overall system are shown in below table.

Table 10-8: Overview of PV System

Overview of PV System		
PV Generator Output	5000	kWp
PV Generator Surface	27,945	m^2
Number of PV modules	16,667	
Number of inverters	3	
Capacity of 1 module	300	Watts
Total Energy Generation	5,023	MWh
Specific Annual Yield	1,005	kWh/kWp
Performance ratio	89.9%	
CO2 Emissions Avoided	3,013	Tons/year

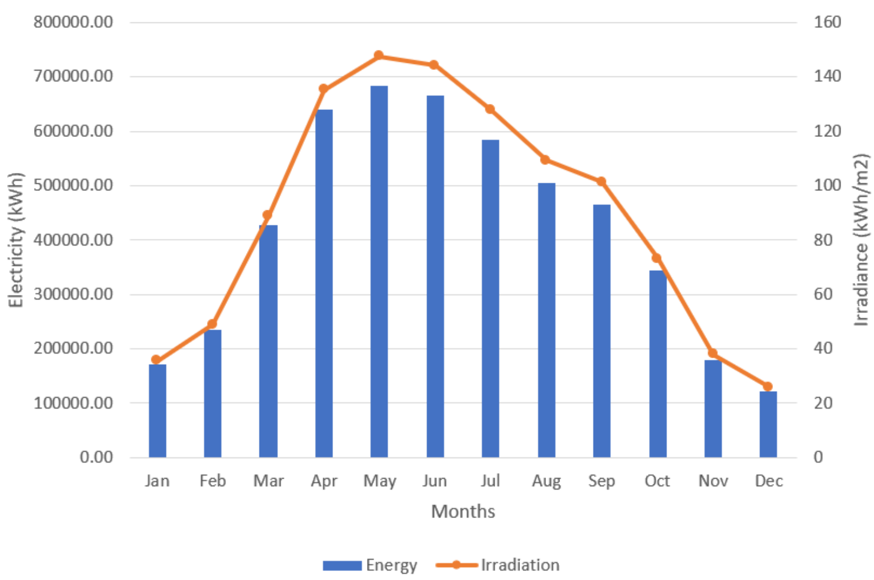


Figure 10-16: Monthly energy generation and irradiation on optimum tilt (Source: Self interpretation based on PVSol Results)

<u>Cost benefit analysis: Market Overview:</u>

Challenges for investment: There are certain challenges regarding solar projects in Ireland as there are currently no large-scale solar farms (SEAI, 2019). As expressed by the Irish government, Solar farms are now considered economically feasible (Cadogan, Solar Farms still some way off , 2019). Despite that there was an absence of support for solar technology under RFITT 1, 2 and 3. Accordingly, no reference price for commercial solar could be found in Ireland. This represents a challenge for the financial calculations. Additionally, there are no planning guidelines for solar farms (SEAI, 2019). The planning documents shared by SEAI are those developed for the UK (SEAI, 2019).

Opportunities for investment:

(1) Policy: Under the planned RESS scheme, possible opportunities for investment could be considered. As has been illustrated in chapter 8, the RESS is designed to enable new technologies such as solar and offshore wind. Additionally, the new scheme is designed to enable community participation as previously illustrated.

(2) Market: Planning permissions has been granted by the Clare County council in 2016 to Terra Solar (Danaher, 2016). An update could not be found regarding the outcome. Another planning permission was granted to the global energy firm, Engie Developments Ireland Ltd (McMahon, 2019). Additionally, it was reported that in 2018, three planning permissions were granted for Solar PV in Co Clare (McMahon, 2019), however there has been an appeal from the community regarding the project due to visual impacts. Accordingly, a community owned projects may be a possible solution to mitigate that. All these can be considered as indicators to the possibility of future markets as it seems that there is a growing interest for solar in Co Clare. On a country level, in 2019 it was reported that solar projects amounting to 1 GW capacity is in the stage of planning permission and over 1.5 GW capacity has been contracted for the grid (Cadogan, Solar Farms still some way off , 2019), the current status of these projects are not clear.

Investment analysis:

In order to conduct this analysis, three scenarios were assumed as shown in the below figure:

Scenario 1 : Advanced markets

- Costs based on the German market
- Installation costs: 1023 Euro per KW
- O&M costs: 23 Euro per KW per year

Scenario 2: progressing markets

- Costs based on the UK market
- Installation costs: 1258 Euro per kW
- O&M costs: 32.5 Euro per KW per year

Scenario 3: New Markets

- Such as in Ireland
- Installation costs: 1,534 Euro perkW
- O&M: 40 Euro per KW per year

Figure 10-17: Scenarios assumed for community owned solar project

For scenarios 1 & 2, costs are based on the data provided from (IRENA , 2018) for markets in Germany and UK. The reason for choosing these markets is to illustrate the investment along different stages of the possible market development; advanced as in Germany, progressing as in UK. Based on the cost difference of 22% between these two markets, the costs are assumed for an emerging market similar to the Irish situation as shown in Scenario 3. To find the selling tariff, an IRR of 7% was assumed in order to make the investment attractive for the shareholders.

The table below summarizes the input parameters used for the investment calculations, the scenarios adapted and the results. The fixed parameters for all scenarios are as follows: project life cycle is 20 years, loan maturity 15 years, depreciation of 20 years and debt share of 80%. The type of loan considered is equal repayment based on the information collected from the contacted funding entities. The calculations were done for each scenario based on an interest rate of 3% and 6% as they represent the highest and lowest rates offered as illustrated in the funding overview. The degradation of the PV module and uncertainty are assumed to be 0.5% and 3.5% respectively (Husseini, 2018) (ABREU, 2018). The tax and inflation rates in Ireland are 12.5% and 0.95% as mentioned in the section covering wind.

Table 10-9: Investment analysis calculation for Solar PV (Source: Authors calculations)

	Inputs			
	Total investment cost ('1000 EUR)	**Total O&M ('1000 EUR)**	**Interest Rate**	**Tariff (Cents per KWh)**
Scenario 1	5,115.00	116,344.93	3%	13
			6%	13
Scenario 2	6,287.60	162,882.90	3%	17
			6%	17
Scenario 3	7,670.85	198,717.13	3%	21
			6%	21
	Outputs			
	NPV ('1000 EUR)	**Payback Years**	**LCOE (Cents per KWh)**	
Scenario 1	1,980.82	13	10	
	862.73	15	11	
Scenario 2	2,469.83	13	12	
	1,171.62	15	13	
Scenario 3	3,014.49	13	15	
	1,328.71	15	16	

Based on the above, it was found that the tariff needed to make the investment favorable is 21 cents per KWh. Which is regarded as relatively high compared to other technologies such as wind. However, as the maturity of the market increases as shown in scenarios 1 and 2, the tariff needed decreases which makes the technology more attractive.

Figure 10-18, shows the cash flow available for shareholders after the loan repayment during the project life cycle. This is based on scenario 3 for an interest rate of 6% and equity share of 20%. As can be observed from the graph, the cash flow increases from 46,247 Euro in the second year of the investment until it reaches a maximum of 624,267 Euro in year 16. Following that, it slightly decreases; due to the degradation of the module; until it reaches 588,992 Euro by the end of the project life cycle. If the number of participants in the project is assumed to be 150 as suggested by RESS, this makes the share per person in each year as shown in Figure 10-19, which ranges from a minimum of 308 Euro per person to a maximum of 3,926 Euro per person. Comparing with the current rate on the savings account in Ireland (AIB, 2020); this share can be considered relatively acceptable. In addition, this money could be reinvested into the community which could result in the development of further projects and accordingly higher social benefits. Also, based on the total energy generation of the plant showed above of 5,022 MWh/year, this could cover up to 28% of the total local demand in Loop Head.

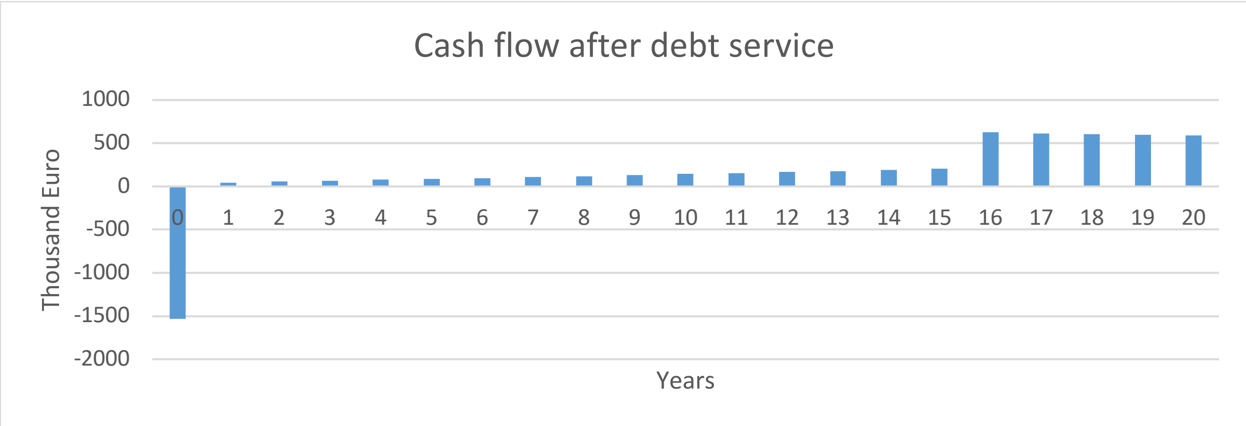


Figure 10-18: Cash flow after debt service for shareholders (Source: own calculation)

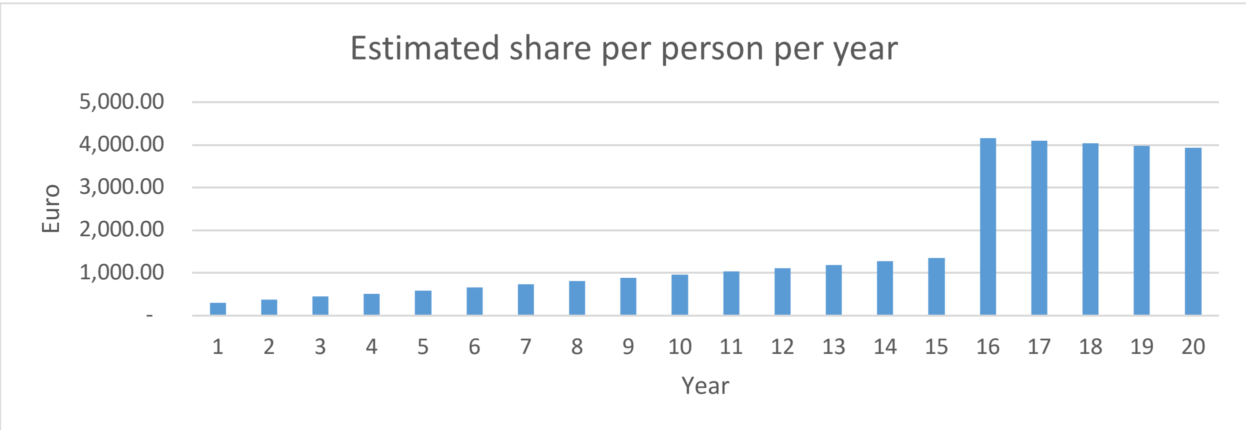


Figure 10-19: Estimated share per person per year based on total number of participants of 150 (Source: own calculation)

Given the current market conditions mentioned above and the expected RESS, it seems that a market may develop for solar in Ireland due to the general interest. However, to make the investment attractive, support is needed from the government regarding the initial investments in that technology. As for new markets to develop, subsides from governments are needed. Even though, initial investments in new markets have some risks due to the market immaturity, however there may have some benefits regarding higher market share.

10.5 Community Heating

In this section, an overview regarding a district heating (DH) design will be presented based on the technical parameters presented in chapters 6 and 11. The reason for suggesting a DH network is the high dependency on oil for heating and accordingly resulting in money leaving the community in addition to the environmental impacts form using oil. Secondly, the nearest injection point to the gas network is in Ennis which is around 55 km from Kilkee (Gas networks Ireland , n.d.). A district heating network may provide a local market for heat from a biogas plant.

A complete and integrated model was built, linking all aspects needed for the DH project. Starting with the basic resource assessment, transport optimization, demand estimation, DH design scenarios and the complete investment analysis. This model was integrated in the overall model presented to the community. In addition to the DH network scenario, a cogeneration of heat and power (CHP) option and a scenario that includes the upgrade to methane were considered. The results of these scenarios can be observed from the model. In addition, ArcGIS was used to map the approximate route of the DH network and for calculating the piping length required.

Market overview:

There are many factors which can be considered to make the market attractive for investment in AD in Loop Head

(1) **Local interest:** As has been illustrated in the farming section, an interest is expressed from the farmers' community in Loop Head. The AD plant is needed to be complemented in a project that could benefit the community; as such a DH is proposed.

(2) **Existing markets for AD in Ireland**: Until 2014, the number of AD plants in Ireland was reported to be 6 (Auer, 2016).

(3) **Regulations supporting Bioenergy:** There has been government support for Bioenergy under REFIT 1, 2 and 3. Additionally, REFIT 3 was only supporting bioenergy and AD CHP for electricity. Also, the current active support scheme for renewable heat (Langton, 2019) supports heat generation from biogas with the incentive shown in the below table for a duration of 15 years.

Table 10-10: Incentive for Renewable heat (Data source: (Langton, 2019))

Tier	Lower Limit (MWh/yr)	Upper Limit (MWh/yr)	AD (c/KWh)
1	0	300	2.95
2	300	1,000	2.95
3	1,000	2,400	0.5
4	2,400	10,000	0
5	10,000	50.000	0
6	50,000	NA	0

However, there are some challenges regarding the investment, as has been observed during the literature review conducted for this work such as the investment costs and O&M which are limited to certain capacities and feedstock mix (SEAI, 2017).

Heating demand overview:

The use of heat in district heating (DH) systems is a potential way of valorising heat from an AD scheme. The scale of the district heating system changes from very small-scale to large-scale (Rutz D. , 2015). Economies of scale from the supply side and demand side play a critical role in the viability of a district heating project. Heat from biogas plants can be used to supply part of the heating demand of Kilkee as seen in the chapter Section 9.1.2. The highest domestic space heat demand is in Kilkee (2,178 MWh/year), in addition to the demand from residential sector in Kilkee, there is a high heat demand from the commercial sector, as has been illustrated in previous sections. Specifically, "Water World", which amounts to 147.8 MWh during its three months of operation and the demand from the hotels which amounts to 715.7 MWh/year.

The heating demand in Kilkee for the design of the DH network can be considered in 3 main types of consumers. Hotels; the swimming pool in Water World; and the space heating demand in houses. Figure 10-20 presents the monthly heat load profile, based on degree-days of the year 2018. Hotels present an average monthly load between 42 MWh when the occupancy is low, and 90 MWh/month during the high tourist season. Water World has a heating demand that along 3 months of the year. Houses in Kilkee use in average 47 MWh/month of heat during wintertime (in the figure is represented heat demand of only a fraction of 49 houses).

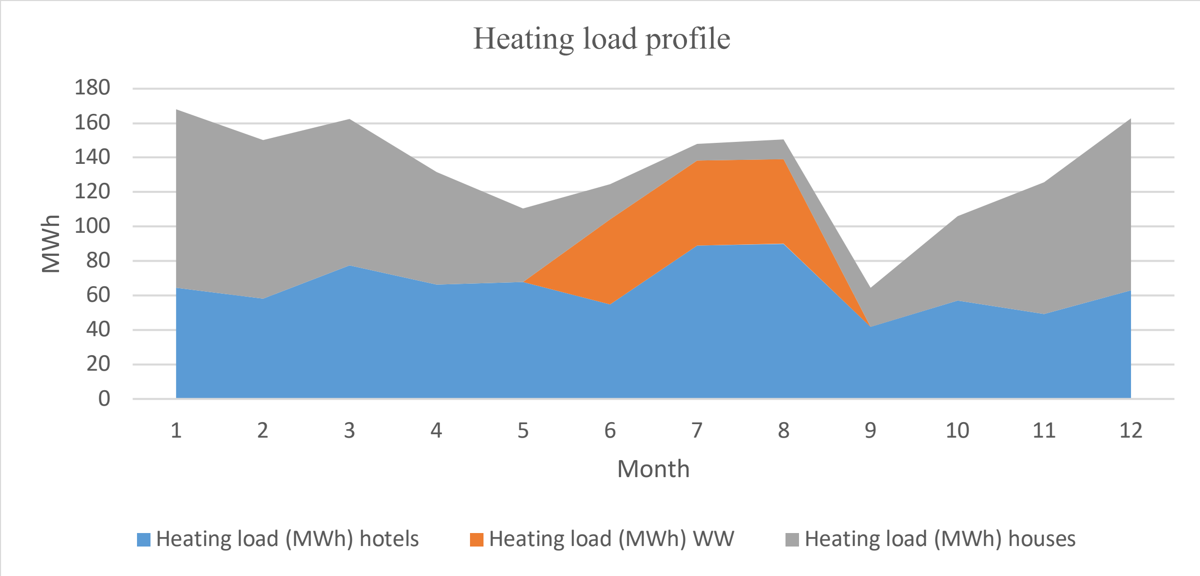


Figure 10-20: Heating load profile from selected consumers – Source own calculations.

<u>DH Network design</u>

To consider the DH design, the methodology adapted was to find an anchor load (important consumer) close to the AD plant; in this case the main anchor load considered was Water World. In order to design a cost-effective district heating, areas with the highest heat demand will be targeted first. Based on different iterations presented in the figure below, the DH network is expanded to the main consumers covering the houses along the way. This approach will allow increasing the amount of heat delivered per area, minimizing the investment cost per unit of water pipes to distribute the heat. Figure 10-21 present an initial layout used as approximation of the distances that can be covered in the DH network, by no means should be considered as final design.

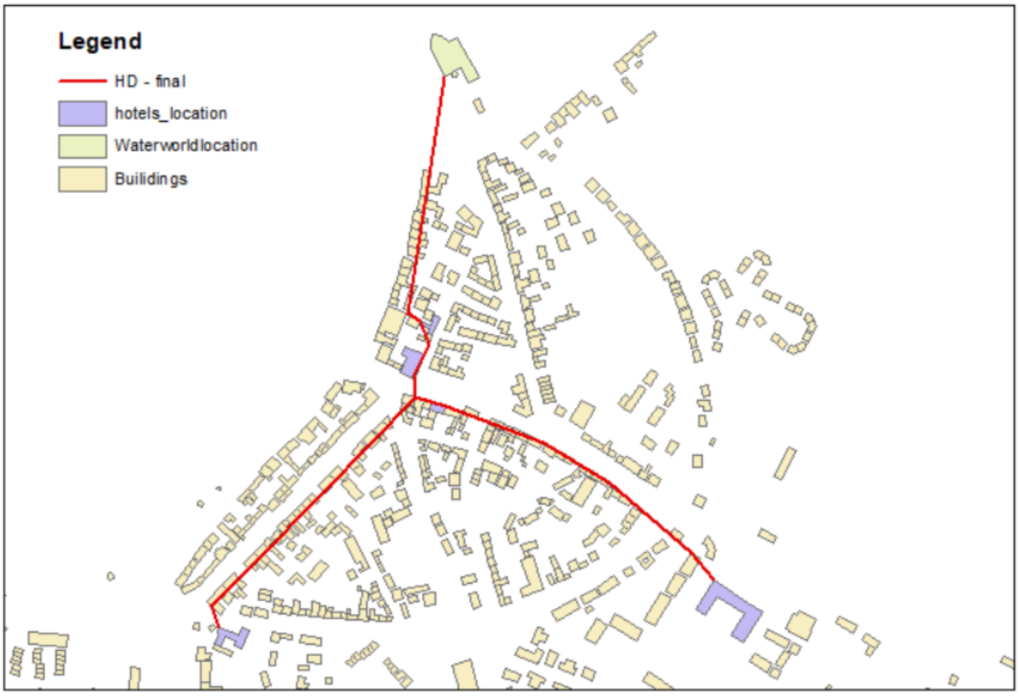


Figure 10-21: District heating configuration. Pipe locations are approximate

Figure 10-21 presents the configuration of the different district heating iterations. Heat demand is based on own calculations explained in the Section 4. The cost of piping considered is 400 euros/meter (Energy Technology Systems Analysis Program (ETSAP), n.d.). Analysis of different scenarios will allow to find the optimal production cost per unit of heat delivered. This allows to understand the most feasible scenario for the DH community owned.

Table 10-11: District heating configuration

District heating configuration	Heat demand (GWh)	Investment cost of the piping extension (Euros)
Connection to anchor load	0.14	98,487
Connection to 1 hotel	0.27	203,847
Connection to 2 hotels	0.38	212,967
Connection to 3 hotels	0.47	226,127
Connection to 4 hotels	0.75	373,047
Connection to 5 hotels	0.94	498,127
Connection to 5 hotels + houses extended	1.25	729,807

Investment analysis:

The investment analysis was conducted covering all aspects of the AD plant in terms of transport and construction of the DH network. Based on the analysis presented in the farming section, in order to reduce the investment costs, a gas pipe will be laid instead of a DH pipe from the AD to the anchor load, where an existing and oversized boiler unit will be reconfigured to work as a district heating central. Starting from the anchor load, DH pipes will be used to connect to the houses and hotels.

Table 10-2 provides an overview of the inputs and outputs of the investment analysis. The fixed parameters are as follows: project life cycle is 20 years[13] based on the lifetime of the AD, loan maturity 15 years, depreciation 20 years. Equal repayment is the loan type considered and an inflation rate of 0.95%. Additionally, a debt share of 80% is assumed for all configurations and an interest rate of 3%. The selling price was fixed at 100 Euro per MWh to be comparable with the heating price from oil (SEAI, 2017). Additionally, the investment costs and O&M were based on the data from (Danish Energy Agnency, 2020) and the investment cost for the AD plant from(Brian H. Jacobsen, 2013) which ranges from 53 Euro/ton annual input to 66 Euro/ton.

Table 10-12: Investment analysis of the DH network based on the BAU demand case of the anchor load (Data source: Author's calculations)

	Total Investment cost including piping (EUR)	**Total O&M Including slurry transport (EUR)**		
Connection to anchor load	211,233	9,193		
Connection to 1 hotel	413,953	16,054		
Connection to 2 hotels	507,310	22,051		
Connection to 3 hotels	586,955	27,143		
Connection to 4 hotels	954,420	45,212		
Connection to 5 hotels	1,223,456	57,227		
Connection to 5 hotels + houses extended	1,688,498	77,596		
Outputs				
	NPV ('1000 EUR)	**IRR**	**Payback years**	**LCOH Cents/kWh**
Connection to anchor load	-71,957	-1.07%	21	15.9
Connection to 1 hotel	-140,288	-1.03%	21	16.1

[13] District heating networks have a lifetime that may exceed 30 years (ETSAP, 2013)

Connection to 2 hotels	-118,160	1.1%	21	14.6
Connection to 3 hotels	-111,375	1.1%	21	14.1
Connection to 4 hotels	-207,526	0.73%	21	14.4
Connection to 5 hotels	-302,363	0.31%	21	14.7
Connection to 5 hotels + houses extended	-848,414	-3.39%	21	15.2

Based on the figures presented above, it can be observed that the investment in DH seems unfavourable due to the high payback period, low IRR and negative NPV. This is due to the high investment costs and O&M. Figure 10-22 presents the necessary support needed as percentage of the investment to have an NPV of 0, meaning the point where the investment pays back. In this case the IRR is 3.54% and the LCOH varies between 13.17 and 11.18 cents per kWh.

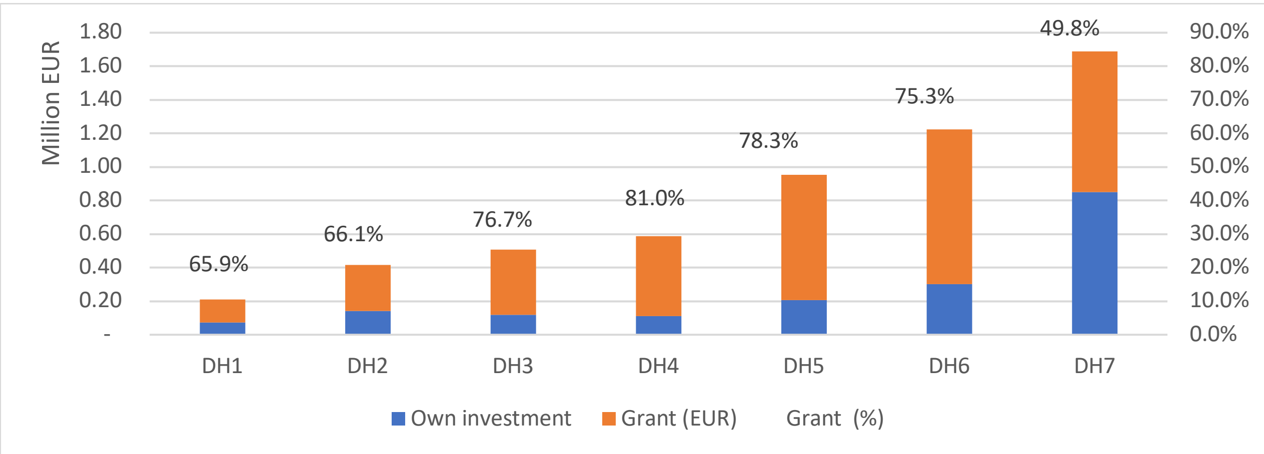


Figure 10-22: Percentage of incentive needed to make the investment favourable (Data source: Author's calculations)

A second analysis was done by increasing the demand of the anchor load from 0.147 GWh per year to 0.5 GWh per year. Based on the assumption that the operation time of the anchor load will be extended to cover the whole year instead of only 3 months as in the above-mentioned case. The results are as shown in the below table.

Table 10-13: Investment analysis of the DH network based on the extended operation time of the anchor load

	Total Investment cost including piping (EUR)	**Total O&M Including slurry transport (EUR)**
Connection to anchor load	418,977	29,013

Connection to 1 hotel	684,687	36,560		
Connection to 2 hotels	778,054	44,483		
Connection to 3 hotels	857,698	50,162		
Connection to 4 hotels	1,225,164	69,059		
Connection to 5 hotels	1,494,200	82,419		
Connection to 5 hotels + houses extended	1,959,241	102837		
Outputs				
	NPV ('1000 EUR)	**IRR**	**Payback years**	**LCOH Cents/KWh**
Connection to anchor load	24,884	4.2%	18	12.13
Connection to 1 hotel	-51,509	2.6%	21	13.06
Connection to 2 hotels	-53,639	2.7%	21	12.99
Connection to 3 hotels	-53,836	2.8%	21	12.94
Connection to 4 hotels	-471,128	-1.5%	21	13.49
Connection to 5 hotels	-634,756	-2.1%	21	13.94
Connection to 5 hotels + houses extended	-912,834	-2.8%	21	14.51

As can be seen from the table that NPV seems to have slightly improved compared to the BAU for certain configurations especially the first one. Using this case as reference, the optimal heating demand to generate income can be estimated. The following figure presents the results of 3 scenarios that consider different investment cost. In the current situation, profit can be generated if the heating demand in the anchor load (swimming pool) is between 0,47 and 1 GWh/year. If incentives of 15% are applied to the capital cost with a grant, profit can be generated with a heating demand of 0.27 GWh/year. If this demand increases to 1GWh, 17,373 euros of profit can be generated every year. It should be noted that the profitability of the project depends on the heating demand and the level of incentives in the capital costs. Additionally, it should be noted that after 1GWh of heating demand supplied, the RHI (renewable heat incentive) is significantly reduced as mention in section 12.5. Therefore, the AD project should be sized considering the heating tariff incentive.

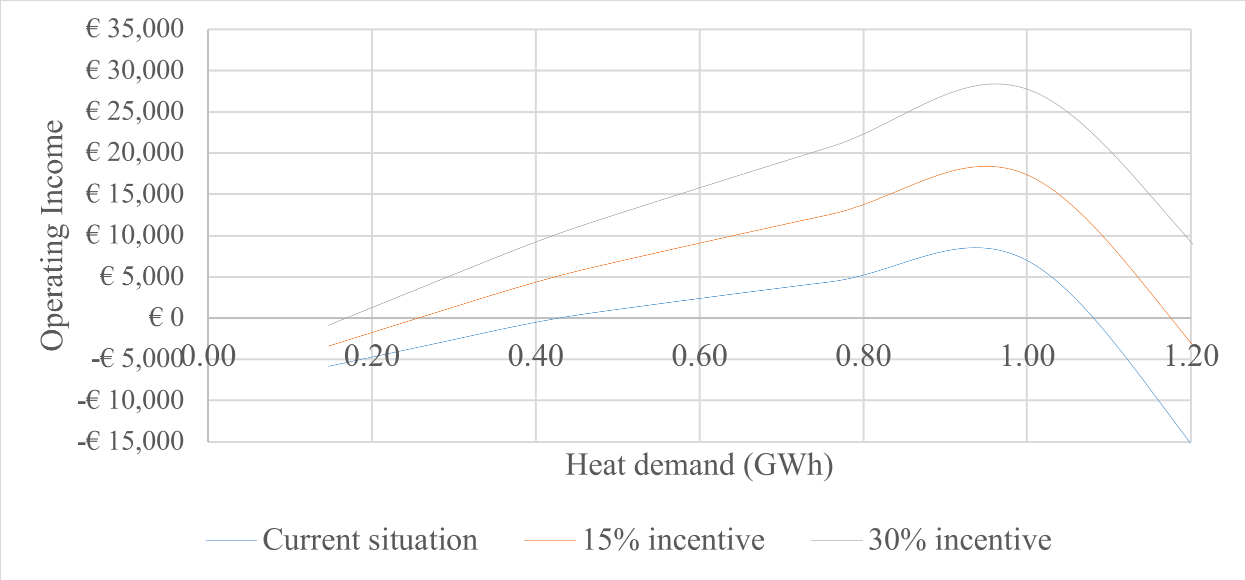


Figure 10-23 Optimal heat demand in different scenarios

It can be concluded based on this preliminary analysis that the AD plant and thus the DH network could be viable subjected to certain criteria such as; an enhanced investment costs, which could be achieved via partnerships, grants and support from interested developers.

The work done in this section is subjected to further enhancement, it should be noted that the analysis was done based on preliminary investment figures and technical assessment. The main objective of this analysis is to establish a basic material which could be used for further development. Accordingly, certain aspects should be considered in future analysis, such as the seasonality of the heat demand, insulation of the pipes, heating deficit in down time, among others.

10.6 Conclusion

This chapter presented an overview of the different aspects of community owned projects, in terms of funding, partnerships, organization under the expected RESS, additionally examples from existing community owned groups were illustrated. Also, an overview was presented regarding possible community owned projects for different technologies such as solar, wind and DH in addition to the energy efficiency for the community. It can be concluded for this overview, that a community owned project could be possible in Loop Head, however support is needed from the government to enable favourable investments in new markets. The overall work in this chapter can be considered preliminary and further research could be carried out. Especially, following the legalisation of the RESS, as more clarity will be available regarding the power prices for the proposed technologies.

11 Pre-Feasibility study for Public Transport

The aim of this study was to evaluate an option for public transport in the Loop Head area, and the feasibility of using an electric minibus, in order to reduce the reliance on imported fuels, or a conventional diesel minibus.

11.1 Vehicles comparison

For the Electric Minibus the specifications of a 16 passenger's low floor minibus available in the European market with 92 kWh battery are used. This can provide up to 160 km of range on a single charge and a charging efficiency of 97% (Mellor, 2019). The assumed lifespan of the vehicle is 321,000 km (Cagatey, 2019). The fuel economy calculated is 0.57 kWh per km travelled.

For the Diesel minibus the specifications used are also from a 16 passenger's minibus available in the European market, with a lifespan of 250,000 km (Craig Dun, 2015) and a fuel economy of 0.12 litres of diesel per km travelled.

Summary of the parameters of two types of vehicles are shown in table below:

Table 11-1: Parameters for Diesel Minibus and Electric Minibus

Specification	**Diesel**		**EV**	
Type	Minibus		Minibus	
Passengers capacity	16		16	
Fuel type	Diesel		100% Electric	
Lifespan	250,000	km	321,000	km
Battery size	-		92.00	kWh
Fuel Economy	0.12	l/km	0.57	kWh/km
CO_2 emissions per year	2.68	kg CO_2/l	0	kg CO_2/l
Charging Efficiency	-		0.97	%

11.2 Economic Assessment

Table 11-2 shows the capital cost assumed for the Diesel minibus 50,000 Euros and for the Electric minibus 105,000 Euros (Mellor, 2019), if chosen the EV an additional of 5,000 Euros is needed for a charging point and installation (Chen, Kockelman, Kara, & Hanna, 2016) .

Table 11-2: Capital cost for Diesel minibus and Electric minibus

Capital costs (CAPEX)	**Diesel**	**EV**
Cost of Vehicle (included battery)	€50,000.00	€105,000.00
Charging point and installation		€5,000.00

11.2.1 Annual Operational Costs

For the annual operational costs the following components were contemplated:

- Insurance

The insurance cost considered is 1200 Euros per year (Chen, Kockelman, Kara, & Hanna, 2016)

- Fuel Cost:

Fuel cost for Diesel vehicle at 1.32 Euro per litre of diesel (SEAI, 2019).

Fuel cost for Electric vehicle varies according to the charging point, three scenarios were considered. ESB Charging Network a private company that offers a 22KW charging point in Kilkee, the tariff for this charging point is 0.29 Euro per kWh with a 5 Euro monthly subscription fee (ESB, 2019).

For the home charging point the tariff will vary from 0.10 Euro per kWh if it is charge during the night or 0.19 Euro per kWh if it is charge during the day (SEAI, 2019).

The third option identified is the possibility of a community owned charging point that could come from a renewable energy source like wind. The tariff considered at this charging point is 0.05 Euro per kWh since is comparable to the wind energy production cost in the area.

Table 11-3 summarized the fuel cost of diesel and cost of electricity at different charging points.

Table 11-3: Fuel cost for a Diesel and Electric Vehicle

<table>
<tr><th>Parameter</th><th colspan="2">Diesel</th><th colspan="3">EV</th></tr>
<tr><td rowspan="4">Fuel Cost</td><td rowspan="4">1.32</td><td rowspan="4">€/l</td><td>0.29</td><td>€/kWh</td><td>ESB Charging Network</td></tr>
<tr><td>0.10</td><td rowspan="2">€/kWh</td><td>Night Home Charging point</td></tr>
<tr><td>0.19</td><td>Day Home Charging point</td></tr>
<tr><td>0.05</td><td>€/kWh</td><td>Community own charging point</td></tr>
</table>

- Salary Driver

The salary of the driver is calculated based on an average rate of 14 Euros per hour, considering 6 to 8 hours a day depending whether it is 2 or 3 loops per day.

- Maintenance vehicle

Cost of maintenance varies according to the age of the vehicle, for this study it was considered the value of 0.15 Euro per km driven for the diesel vehicle (Sheth & Sarkar, 2019) and for the electric 0.04 Euro per km driven (Logtenberg, Pawley, & Saxifrage, 2018).

- Maintenance of Charging point

For the maintenance of a charging point a value of 50 Euros per year is used (Chen, Kockelman, Kara, & Hanna, 2016).

11.2.2 Revenues

The revenues will depend on the number of passengers per year and the tariff for each ride. The revenues are calculated based on the different scenarios for demand and different tariffs assumed.

11.3 Routes assessment

Different options were taken into consideration for a possible route of a minibus. For example, loop 1 is taking into account the first five rows of the Table 11-4 plus option 1. For calculation it is considered loop 3 with 87.3 km in total.

Table 11-4: Routes estimates distance in kilometres and time

Routes	Distance (km)	Time (minutes)
Kilrush-kilkee	13.1	12
Kilkee-Cross	14.4	15
Cross-Kilbaha	7.7	9
Kilbaha-Light house	5	6
Light house-Kilbaha-Carrigaholt	17.5	24
Carrigaholt-Kilkee direct -Option 1	11.1	11
Carrigaholt-Doonaha-Kilkee - Option 2	13	16
Carrigaholt-Doonaha-Querrin-Kilkee - Option 3	16.5	21
Kilkee-Kilrush	13.1	12
Total loop 1	**81.9**	**77**

Total loop 2	83.8	82
Total loop 3	**87.3**	**87**

11.4 Demand assessment

To estimate a possible demand for a public transport system in Loop Head some assumptions were made based on interviews and data on the tourism season.

First, as mentioned previously in section 4.4, 1764 people used the bus that operates in the Loop Head peninsula in 2019. Assuming an equal distribution among the year, 147 passenger trips per month was taken as a base demand.

Second, According to an interview, the post office in Carrigaholt serves about 400 customers per week during all the year of which roughly 10% to 15% might use public transport since many of them use taxi service or are given a lift by private car owners (Gavin, 2019). In this sense, to be conservative, it is assumed that 5% of the post office customers will use public transport which gives a figure of 80 passengers monthly, which was taken also as base demand.

Third, it is estimated that 24,450 people visited Loop Head lighthouse in 2017 (Clare Echo, 2017).Based on this, it is assumed that some of the visitors will be willing to use a public bus to travel through the Loop Head Peninsula from Kilkee and Kilrush at least once, especially between June and August. Hence, different percentages of visitors (5%, 7%, 10% and 15%) are monthly distributed taking as a reference the data of bed occupancy in the area, from previous interviews.

Figure 11-1 below shows the total number of base demand estimated monthly and yearly; the different percentages of tourists taken in consideration distributed monthly and the aggregate number of the total base demand plus the number of tourist based on different percentages.

	Month												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**total**
Current passengers	147	147	147	147	147	147	147	147	147	147	147	147	1764
Carrigaholt Post office customers	80	80	80	80	80	80	80	80	80	80	80	80	960
Total base demand	227	227	227	227	227	227	227	227	227	227	227	227	2724
5% Tourist	37	37	49	92	116	204	204	204	116	92	37	37	1225
7% Tourist	51	51	69	129	163	286	286	286	163	129	51	51	1715
10% Tourist	74	74	98	184	233	408	408	408	233	184	74	74	2450
15% Tourist	110	110	147	276	349	612	612	612	349	276	110	110	3675
total with 5% of tourists	264	264	276	319	343	431	431	431	343	319	264	264	3949
total with 7% of tourists	278	278	296	356	390	513	513	513	390	356	278	278	4439
total with 10% of tourists	301	301	325	411	460	635	635	635	460	411	301	301	5174
total with 15% of tourists	337	337	374	503	576	839	839	839	576	503	337	337	6399

Figure 11-1: Demand estimation: Own elaboration.

Fourth, in order to calculate if this monthly estimated demand could fit in one minibus, a combination of number of loops per day (2 or 3); number of days per week (2 to 7); 16 passengers (assuming the bus is full on a loop) and 4 weeks per month were multiplied to reach the monthly demand estimation. The fully monthly estimated demand could not be reached with these combinations but the results were taken as the scenarios.

Finally, based on the above mentioned, four scenario were taken in consideration for a sensibility analysis. Scenario 1 considers 3,712 passengers, 4,288 passengers in Scenario 2, approximately 4,736 passengers in scenario 3 and for scenario 4 around 6,080 passengers.

For each scenario, based on the kilometres driven per year, which varies monthly according to the combinations, the annualized costs were calculated. As well, the revenues were calculated based on the number of passengers on each month at different fares.

Figure 11-2 shows the different demand scenarios for public transport which were estimated considering all the figures assumed previously.

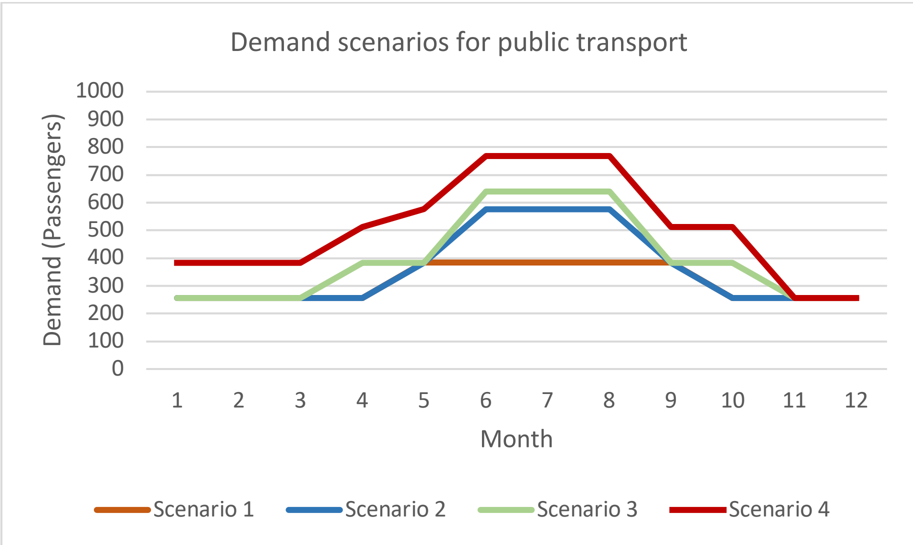


Figure 11-2: Demand Scenarios for public transport. Source: Own elaboration.

11.5 Scenario comparisons

As mentioned previously, four demand scenarios are considered. For each demand scenario, the intersection between the annualised cost (operational costs and investment cost) and the annual revenues were found using different values for the fare, for both diesel and an electric bus with the Home Charging point tariff.

11.5.1 Scenario 1

Figure 11-3 and Figure 11-4 shows the result for the demand scenario 1, it can be seen that for the electric bus about 5.3 Euros should be charged to the user so that the revenues outweigh the costs. While for the diesel bus about 5.7 Euros should be charged.

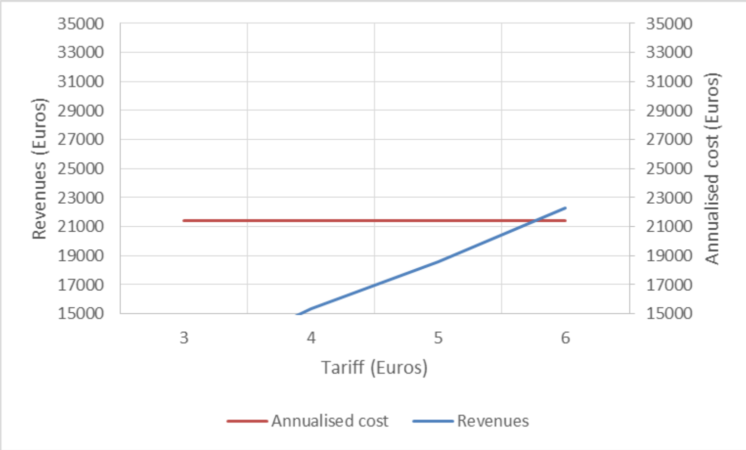


Figure 11-3: Revenues and costs scenario 1- diesel bus

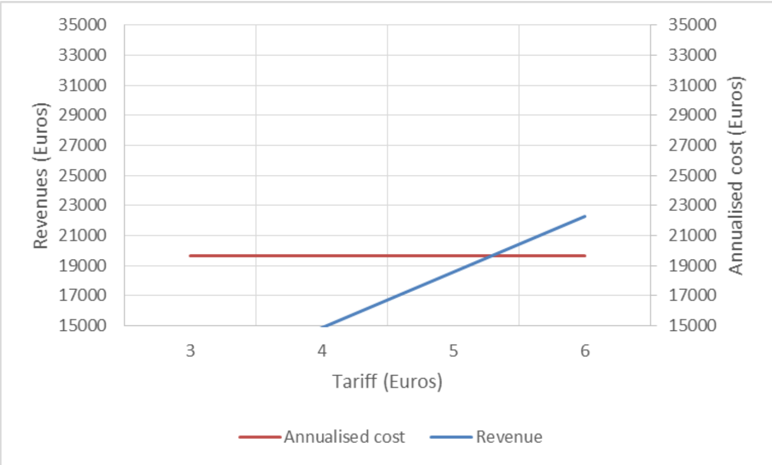


Figure 11-4: Revenues and costs scenario 1- electric bus

11.5.2 Scenario 2

Figure 11-5 and Figure 11-6 present the results for the demand scenario 2. According to these graphs, approximately 5 Euros should be charged to outweigh the costs for the electric bus, whereas about 5.6 Euros should be charged for the diesel bus.

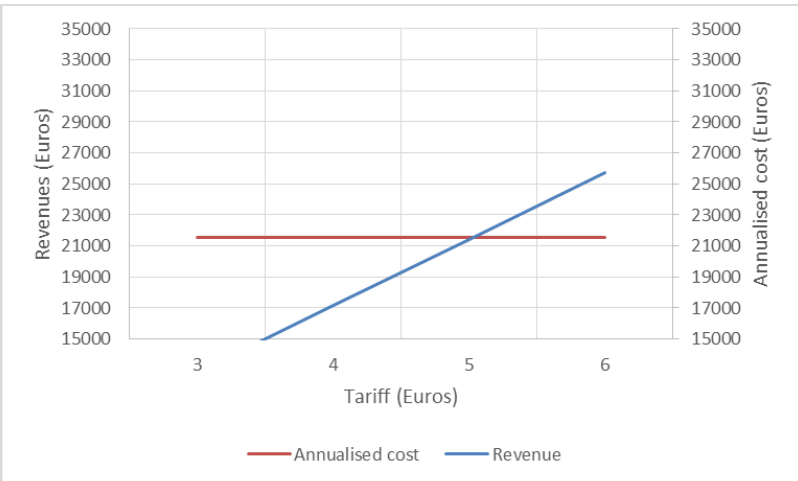


Figure 11-5: Revenues and costs scenario 2-electric bus

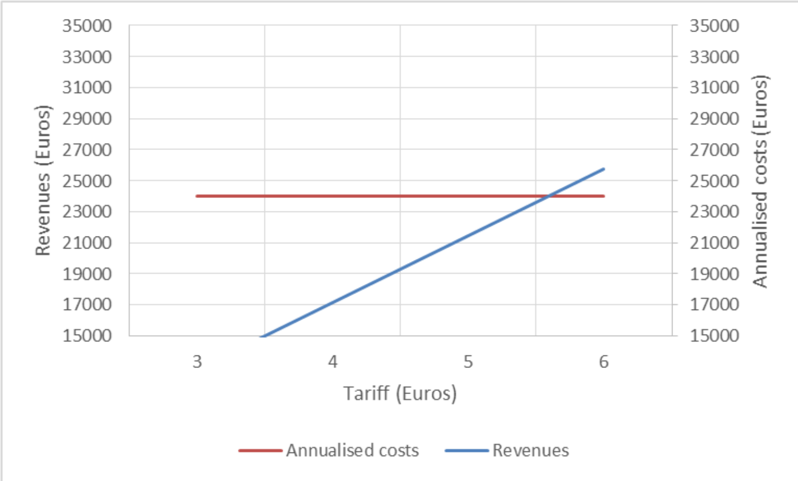


Figure 11-6: Revenues and costs scenario 2-diesel bus

11.5.3 Scenario 3

As shown in Figure 11-7 and Figure 11-8, for the demand scenario 3 roughly 4.8 Euros outweigh the costs for the electric bus, while a higher amount, about 5.5 Euros, is profitable for the diesel bus.

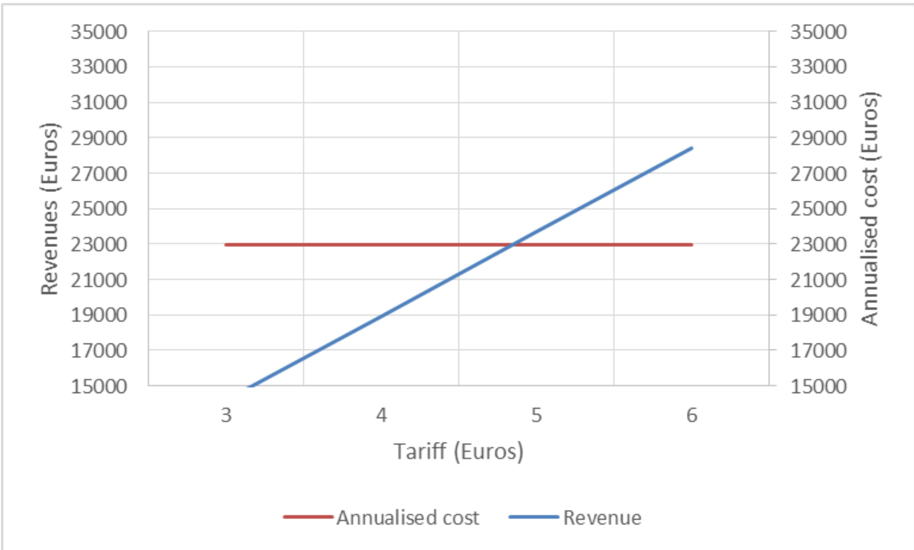


Figure 11-7: Revenues and costs scenario 3-electric bus

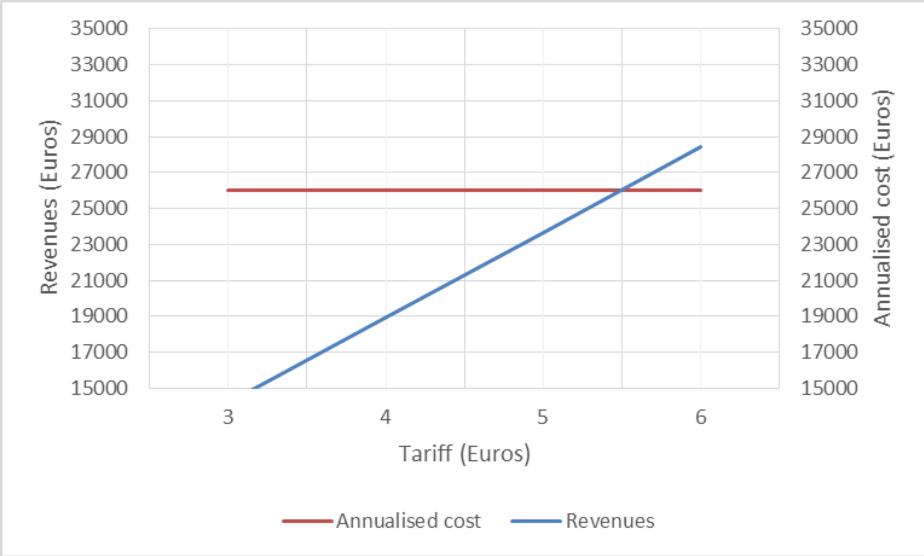


Figure 11-8: Revenues and costs scenario 3- diesel bus

11.5.4 Scenario 4

As for demand scenario 4 according Figure 11-9 and Figure 11-10 the electric bus option will be profitable at a fare of 4.5 Euros, whereas the diesel bus option would be profitable if the fare was approximately 5.25 Euros.

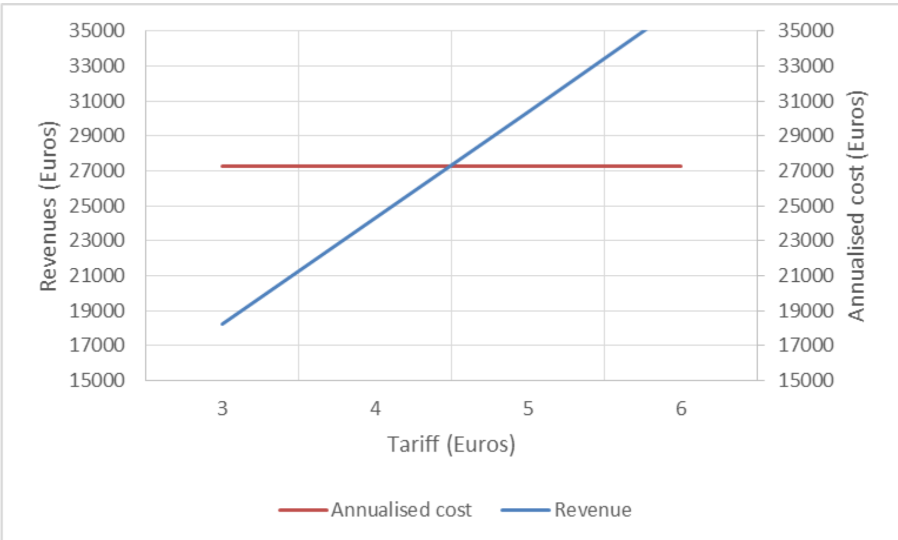


Figure 11-9: Revenues and costs scenario 4- electric bus

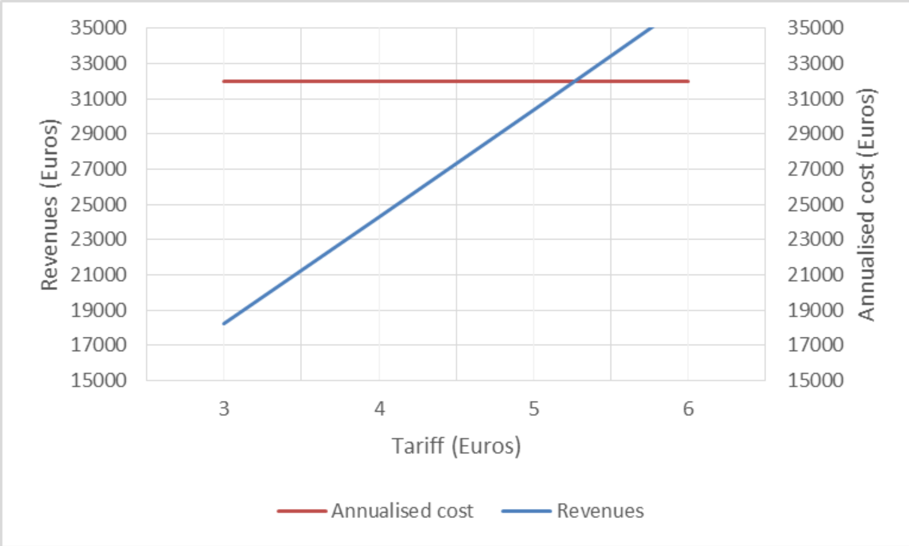


Figure 11-10: Revenues and costs scenario 4-diesel bus

The above-mentioned scenarios show that for public transport sector if an electric bus is selected, the revenues will outweigh the annualised costs at a lower fare compared to a diesel bus.

Figure 11-11 shows an economic comparison between the diesel bus and the electric bus, for the latter one two options are considered based on the charging point. This could be either a home point with a residential electricity tariff or a community-owned point which is assumed to use electrical energy from the wind turbine at a lower price. The values of these tariffs were mentioned previously.

It can be seen that for both electric bus options the fare would be lower than the fare for the diesel option as the demand of passengers is increased. For example, to serve 6, 000 passengers per year, about 5.5 Euros should be charged with a diesel bus to outweigh the costs, while for the electric bus charged using residential electricity tariff, the fare should be around 4.5 Euros and 4.25 Euros for the electric bus charged using a community-owned charging point.

As a conclusion, an electric bus might be a profitable option to provide public transport in Loop Head as long as a cost-effective tariff for electricity for the vehicle is available. Tariffs equal or lower to the ones mentioned in this chapter are suggested.

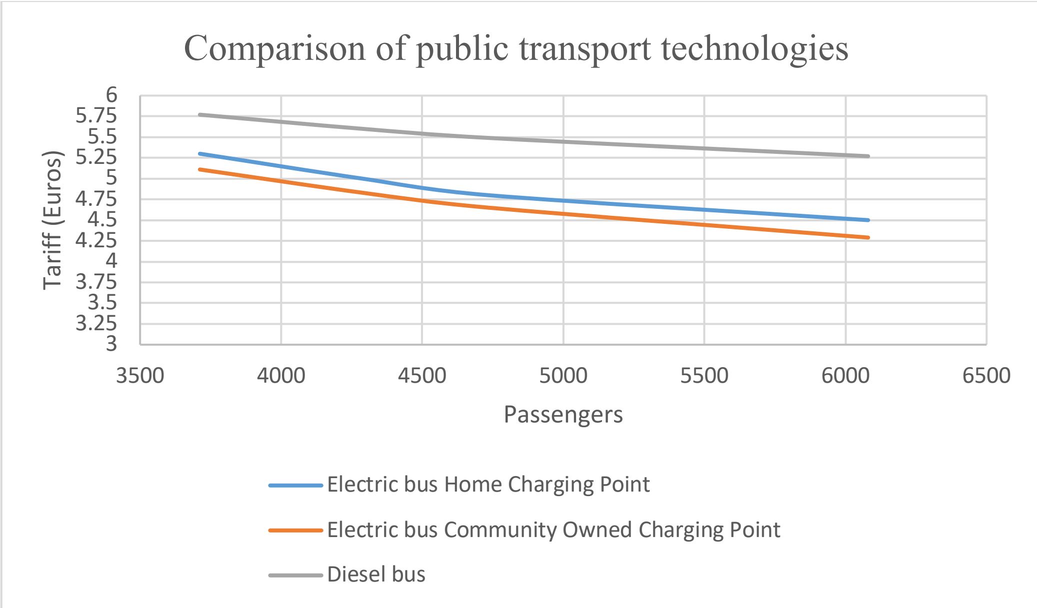


Figure 11-11: Economic comparison between electric and diesel bus considering tariff and number of passengers.

12 Open questions

All the prefeasibility studies presented shows that there is ample space of transition in each sector as far as energy is concerned. The prefeasibility studies could have been refined further but due to different limitations in particular sectors, there are some open questions which still need to be solved in future. These limitations and open questions are listed below:

Residential Sector

- There's is no available data on the number of households that have already been retrofitted under SEAI supporting schemes.
- The percentage of the houses that might become permanent houses.
- The option of introducing to the house a heat pump with solar PV is not considered and that should be considered in further studies.
- In-depth studies in suitable heat technologies for households should be considered in further studies.

Transport

- If local and tourist in the peninsula area would be willing to use public transport more frequently.
- How much are they willing to pay for an improved (more frequency, more routes, environmental friendly) public transport system in Loop Head?

Farming

These questions give a brief research gap that could be considered in the future.

- Could excess generation be diverted to water heating?
- Could Demand (e.g. for the milking robot) be shifted from night to day (Demand side Management)?
- If Policies that set a Feed in Tariff evolve, would a larger PV system be viable?
- The case of Subsidies offered to farmers for an on-farm PV system.

Commercial sector

- What measures are applicable to reduce electricity consumptions for a particular Hotel in Loop Head?
- What is the most cost-efficient heating system for hotels and B&B?
- What are potential systems to supply current accommodation buildings with heating & electricity demands with less environmental impacts?
- What is the future energy demand profile for water world and Kilkee Bay swimming pool?
- What are the energy breakdowns of non-tourism sectors (E.g. Cafés and bars, shops, schools and offices)?

13 Appendixes

13.1 Appendix 1

Heat and water heating calculations for small area (example)

EDNAME	SMALL_AREA	GEOGID		number of occupied HH	[people/HH]	Av HH size [m2]
Kilballyowen	037070002/037070	A037070002/037070003		47	3	96

	Year Built										
	Pre 1919	1919 to 1945	1946 to 1960	1961 to 1970	1971 to 1980	1981 to 1990	1991 to 2000	2001 to 2005	2006 or later	Total	Source
Number of occupied HH (including temporaly	12	7	6	1	4	1	5	10	2	48	[1]
Share of number occupied HH	26%	15%	13%	2%	9%	2%	11%	21%	4%		
BER	F,G	F-G	E,F	D,E	C,D	C,D	D,C	C	B,A		[2]
Average Primary energy use kWh/m2/year	415	415	360	280	212,5	200	187,5	175	75		[2]
Heat consumption [kWh/m2/year]	288	288	250	194	147	139	130	121	52		
Heat consumption [MWh/year]	332	194	144	19	57	13	63	117	10	948	
Share of heat consumption for each age group	35%	20%	15%	2%	6%	1%	7%	12%	1%		
Total HEAT consumption [MWh/y]	261	152	113	15	45	10	49	92	8	744	[3]
of which water consumption [MWh/y]	21	13	11	2	7	2	9	18	4	84	[9]

	Heat technology									
	Oil	Natural gas	Electricity	Coal	Peat	LPG	wood pellets)	Others	average PEF	Source
	1,34	1,19	2,08	1,44	1,38	1,19	1,30		1,44	
Primary Energy factor	1,18	1,13	2,08	1,06	1,04	1,13	1,04			[5]
Efficiency of heat technology	0,88	0,95	1,00	0,74	0,75	0,95	0,80			[6]
share of fuel	22	1	3	7	12	0	1	2		[1]
Share of occupied HH using heat technology	47%	2%	6%	15%	26%	0%	2%	4%		

Sources:

[1] Statistics, C. (2016) Census 2016 Small Area Population Statistics. URL: http://census.cso.ie/sapmap_2016/

[2] CSO statistical release URL: https://pdf.cso.ie/www/pdf/20200122091431_Domestic_Building_Energy_Ratings_Quarter_4_2019_full.pdf

[3] SEAI (2018) Heat Demand Maps. URL: https://www.seai.ie/technologies/seai-maps/heat-demand-map/

[4] Heat Roadmap Europe (2017) URL: https://heatroadmap.eu/wp-content/uploads/2018/11/HRE4_D3.1.pdf

[5] Briefing Note – Derivation and use of Primary Energy factors in SAP URL: https://www.bregroup.com/wp-content/uploads/2019/10/Briefing-note-on-derivation-of-PE-factors-V1.3-01-10-2019.pdf

Methodology for heating demand

1. The data on the number of ocuppied households in each building age group was taken from [1]
2. Based on [2] the level of BER has been associated to each building age group
3. Based on the data from [2] the average primary energy use for each BER level is calculated (average between min and max)
4.The data about the number of households with different central heating fuel type has been taken from [1]
5. Efficiency for each heat technology has been taken from [6] and primary energy factor for each fuel type has been taken from [5]
6. Based on 4 and 5 **Weighted average PEF** has been calculated (assuming that distribution of heat technologies is the same for all Household)
7. Heat consumption for each building age group is calculated by dividing 3/6
8. Heat consumption from [kWh/m2/year] to [MWh/year]
9. Based on 8 the Share of heat consumption for each age group is calculated
10. The total heat demand for each building age group is calculated by multiplying total heat demand of small area [3] by 9

Methodology for water heat calculation

Water heating demand for each small area is calculated multiplying water heating per capita by the population in that small area

"space heating accounted for 61% of residential final energy, or approximately 1 652 ktoe" [7]

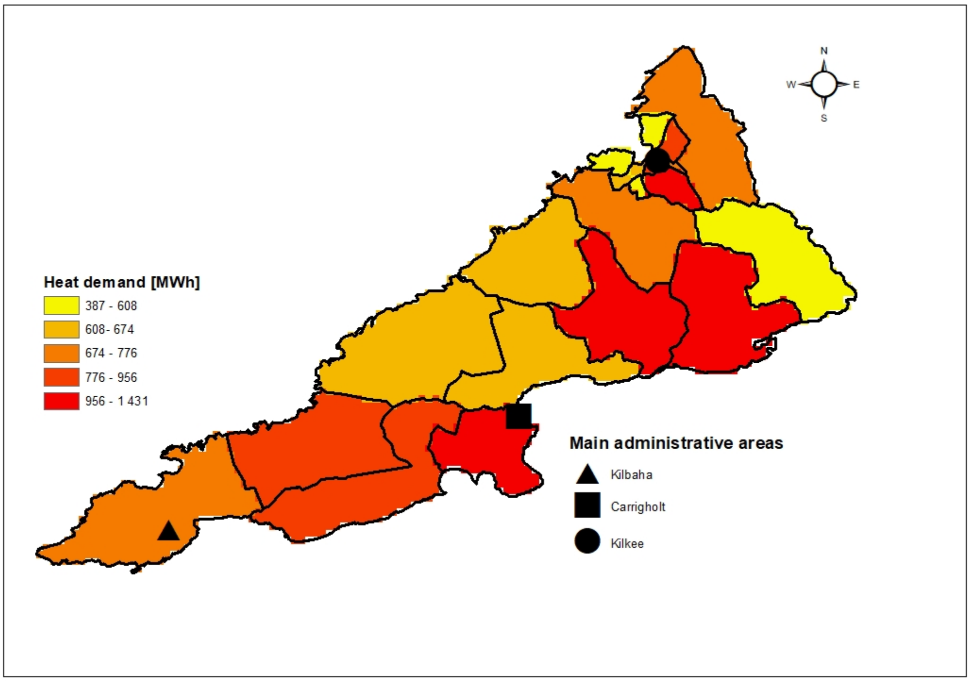
1 ktoe 11630 MWh [8]

1652 ktoe 19212760 MWh

	Population Ireland 2016	Space heating Ireland [MWh]	Water heating share [%]	Water heating per capita
	4 761 865	19 212 760	0,15	0,61
Source	[7]	[7]	[4]	

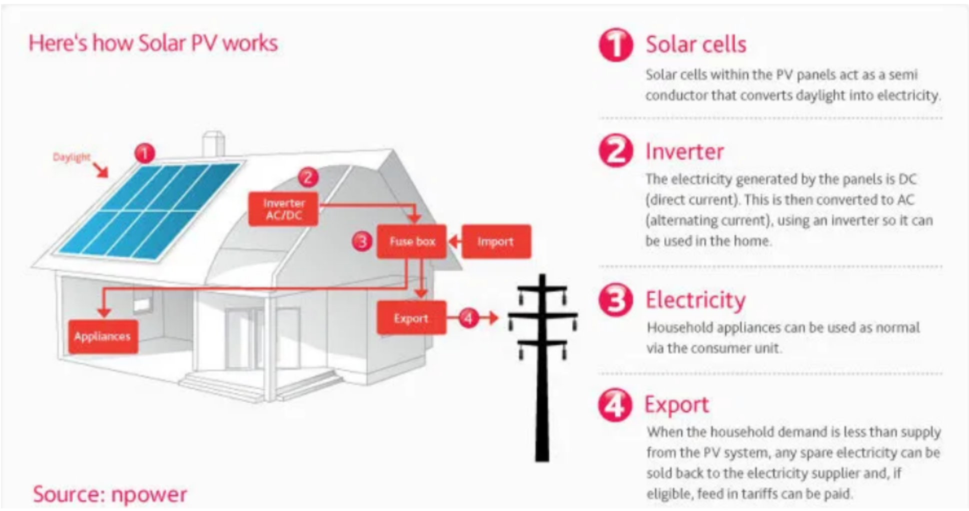
13.2 Appendix 2

Heat demand map of Loop Head (Source: own calculations using ArcGIS)



13.3 Appendix 3

The explanation of how PV system works in the household (Wilson L., 2015)



13.4 Appendix 4

Methodology to calculate the biogas potential

The Table 13-1 below shows the characteristics of feedstock used in this report. The yields for biogas, dry mater content and volatile solids are used to calculate the potential biogas in total annual production of agricultural feedstocks and organic waste.

Table 13-1: Characteristics of the biomass resources used in the biogas calculation

Source	Type	Dry matter content (DM%)	Volatile solid (VS%)	Biogas yield (m^3/kg DM)	Energy content - LHV (KWh/m^3)	Total resources (ton/year)	Practical potential estimation (ton/year)	Practical energy equivalent from biogas (GWh/year)
Agricultural feedstocks	Slurry	8.35% (1)	76.5% (1	0.25 (2	6 (3)	66,249 (4)	59,624	5.71
	Silage	40% (3)	91.7% (1	0.6 (3)	6 (3)	29,360,000 (5)	4,679	6.18
Organic waste	Households	55% (3)	50% (3)	0.3 (3)	6 (3)	237.45	0	0
	Commercial					1,899.97 (6)	0	0

(1) (O'Shea, Kilgallon, Wall, & Jerry, 2016)
(2) (Jacobsen, Luagesen, Dubgaard, & Bojesen)
(3) (Demirel)
(4) Based on the livestock count reported in the farmers workshop.
(5) (CSO.ie, 2019)
(6) Own estimation based on interviews with the commercial sector

The practical potential of slurry has been calculated based on the data of the livestock count from the agricultural census and the workshop developed with the farmers. The yields of manure are presented in Table 13-2.

Table 13-2: Slurry potential yield.

Slurry Potential	(ton/year/head) (1)	Count (head) (2)	Total slurry production (tones/year)
Bulls	5.84	127	740.7
Dairy cows	5.84	2,812	16,423.2
Other Cows	5.20	2,912	15,141.04
Other Cattle	4.10	8,279	33,944.83
Total	-	14,130	66,249.83

(1) (XD Sustainable Energy Consulting Ltd, 2019)
(2) Based on the livestock count reported in the farmers' workshop.

Table 13-3 shows characteristics used in the forestry calculation. Dry mater content and energy content are used to calculate the total energy resources based on average yearly production of forestry products in Loop Head peninsula.

Table 13-3:Characteristics of the biomass resources used in the forestry energy calculation.

Source	**Dry matter content (DM %)**	**Density (kg/m^3)**	**Energy content - LHV (MJ/kg)**	**Annual average production (m^3/year)**
Forestry (broadleaf and spruce)	55% (1)	500 (2)	19 (2)	377.1 (3)

(1) (Department of Agriculture)
(2) (Demirel)
(3) (Department of Agriculture, Food and Marine, 2017)

Feedstock mapping analysis

The following section presents the spatial analysis of the biogas potential from, livestock, silage and organic waste.

Slurry manure production

Based on calculations of the livestock count reported in the farmers workshop. The practical potential of slurry (ton/year) was mapped as shown in the below figure. The highest slurry potential is concentrated near Kilbaha and Carrigaholt accounting for 15,301 (ton/year).

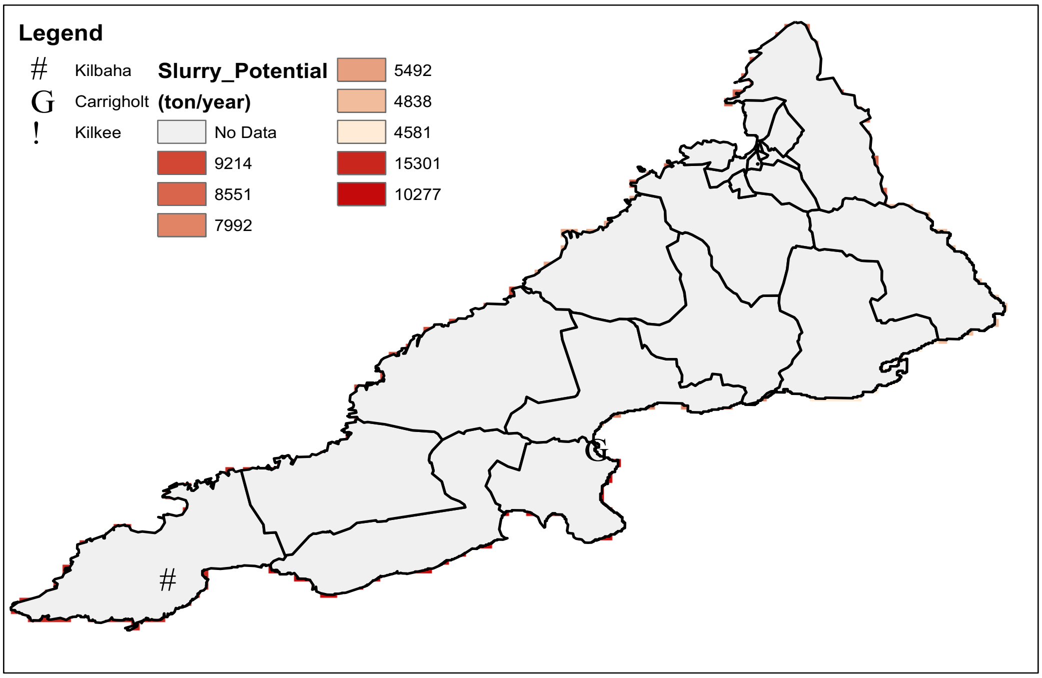


Figure 13-1: Slurry Potential (ton/year)(Data source based on Authors calculations, mapped via ARCGIS)

Silage potential to produce biogas

Biogas potential from silage was mapped as shown in the below figure. It was calculated that the highest biogas potential accounts to 212.13 thousand m³ per year, located in the area surrounding Kilbaha and Carrigaholt.

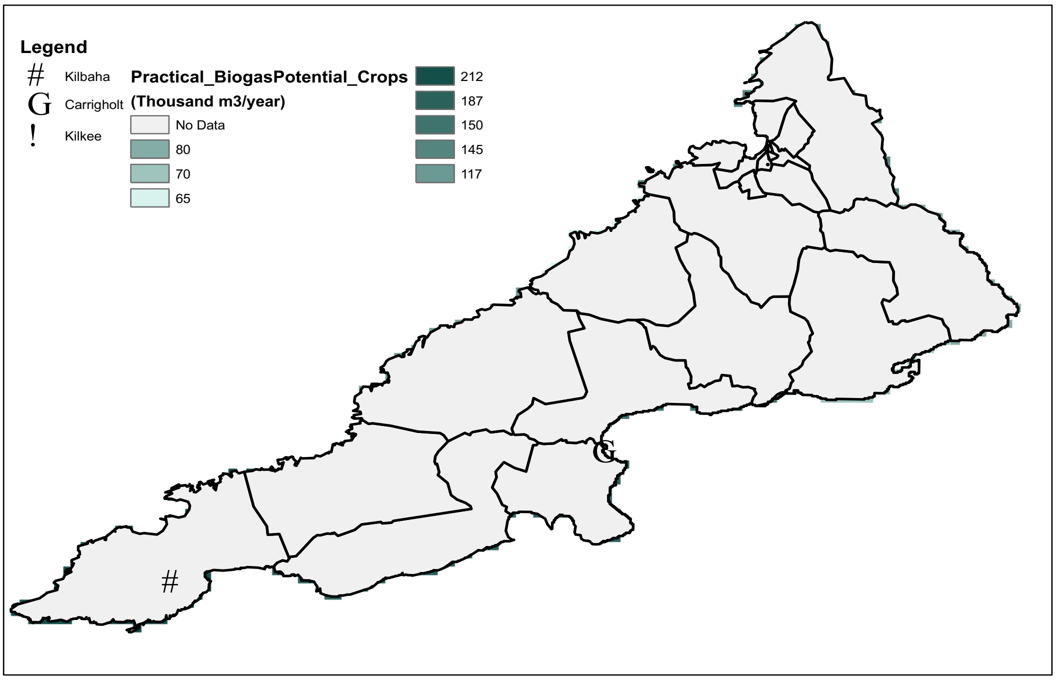


Figure 13-2: Practical Biogas potential from silage (Data source Authors calculations:, mapped using ARCGIS)

Organic waste potential

Based on the Appendix 4 calculations, organic waste production per year was mapped as shown in the figure Figure 13-3. It can be observed that most of the potential is in Kilkee and Carrigaholt, where most of business and population are concentrated. Since organic waste is collected centrally by the company Clean Ireland Recycling where it is processed in an anaerobic digester the potential of organic waste is not considered in the practical potential.

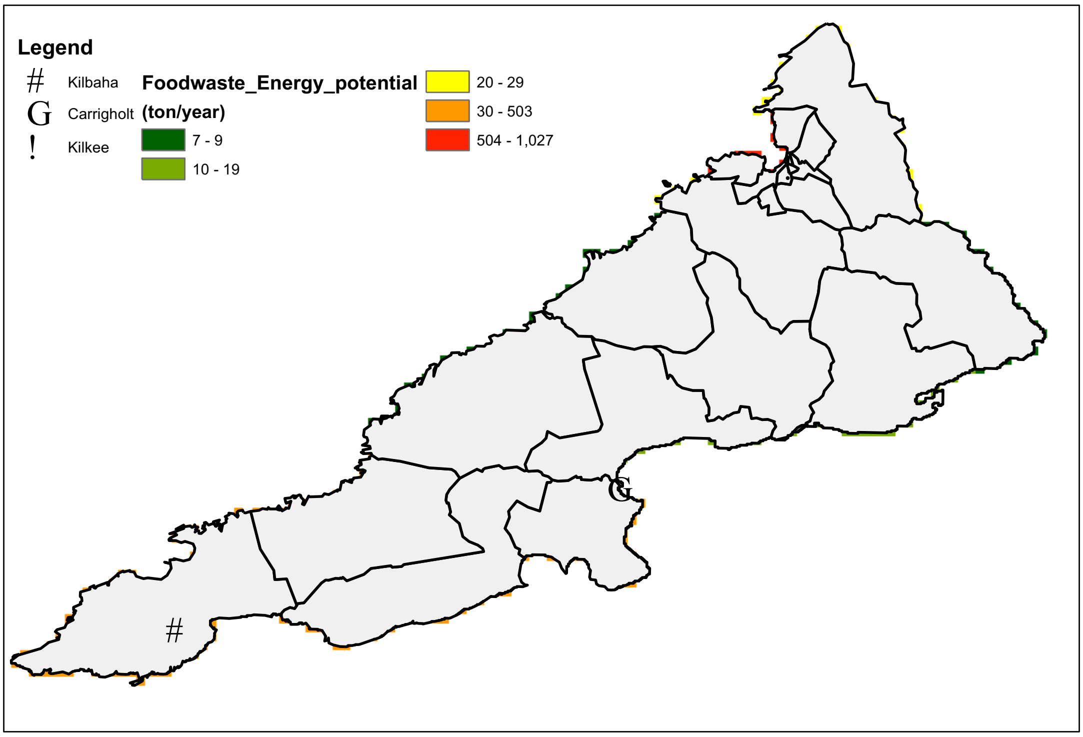
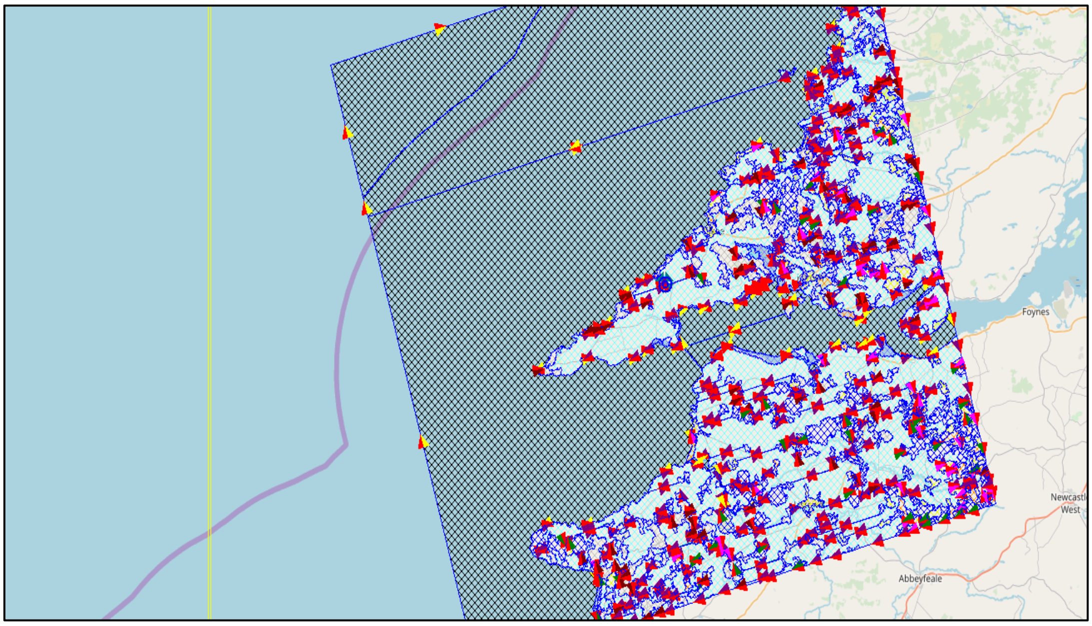


Figure 13-3: Theoretical energy potential from food waste (Data source, mapped via ARCGIS)

13.5 Appendix 5

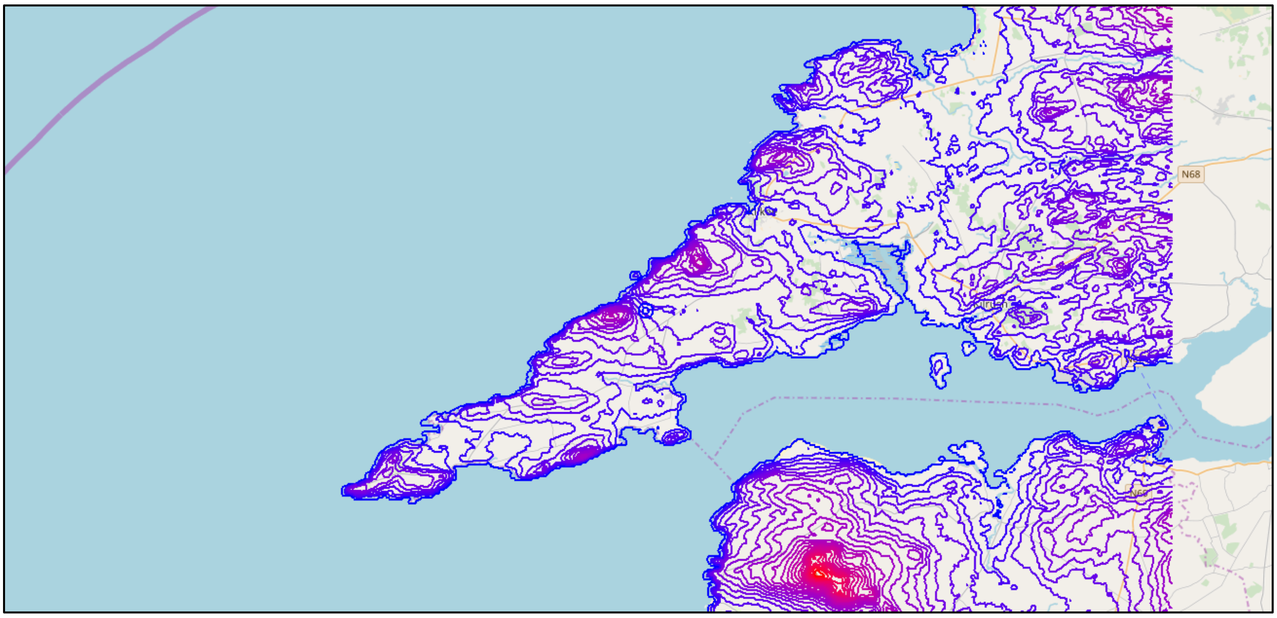
Roughness Calculation with roughness classes based on terrain



Color	Name	Height	Roughness class	Roughness length
	0,0560m(cl.1,5) Complex cultivation patterns 2.4.2	0.0	1.5	0.0560
	0,0000m(cl.0,0) Sea and ocean 5.2.3	0.0	0.0	0.0000
	0,0360m(cl.1,2) Pastures 2.3.1	0.0	1.2	0.0360
	0,0005m(cl.0,2) Intertidal flats 4.2.3	0.0	0.2	0.0005
	0,0100m(cl.0,8) Beaches, dunes, and sand plains 3.3.1	0.0	0.8	0.0100
	0,0184m(cl.0,9) Peat bogs 4.1.2	0.0	0.9	0.0184
	0,0560m(cl.1,5) Non-irrigated arable land 2.1.1	0.0	1.5	0.0560
	0,0560m(cl.1,5) Land principally occupied by agriculture, with significant areas of natural vegetation 2.4.3	0.0	1.5	0.0560
	0,4000m(cl.3,0) Transitional woodland-shrub 3.2.4	0.0	3.0	0.4000
	0,5000m(cl.3,2) Coniferous forest 3.1.2	0.0	3.2	0.5000
	0,4000m(cl.3,0) Discontinuous urban fabric 1.1.2	0.0	3.0	0.4000
	0,0500m(cl.1,4) Inland marshes 4.1.1	0.0	1.4	0.0500
	0,5000m(cl.3,2) Sport and leisure facilities 1.4.2	0.0	3.2	0.5000
	0,0000m(cl.0,0) River 5.1.1	0.0	0.0	0.0000
	0,0000m(cl.0,0) Estuaries 5.2.2	0.0	0.0	0.0000
	0,0348m(cl.1,1) Salt marshes 4.2.1	0.0	1.1	0.0348
	0,5000m(cl.3,2) Port areas 1.2.3	0.0	3.2	0.5000
	0,5000m(cl.3,2) Broad-leaved forest 3.1.1	0.0	3.2	0.5000
	0,5000m(cl.3,2) Mixed forest 3.1.3	0.0	3.2	0.5000
	0,0560m(cl.1,5) Natural grassland 3.2.1	0.0	1.5	0.0560
	0,0600m(cl.1,6) Moors and heathland 3.2.2	0.0	1.6	0.0600
	-1,0000m(cl.-194,6) NO DATA	0.0	-194.6	-1.0000
	0,1000m(cl.2,0) BACKGROUND	0.0	2.0	0.1000

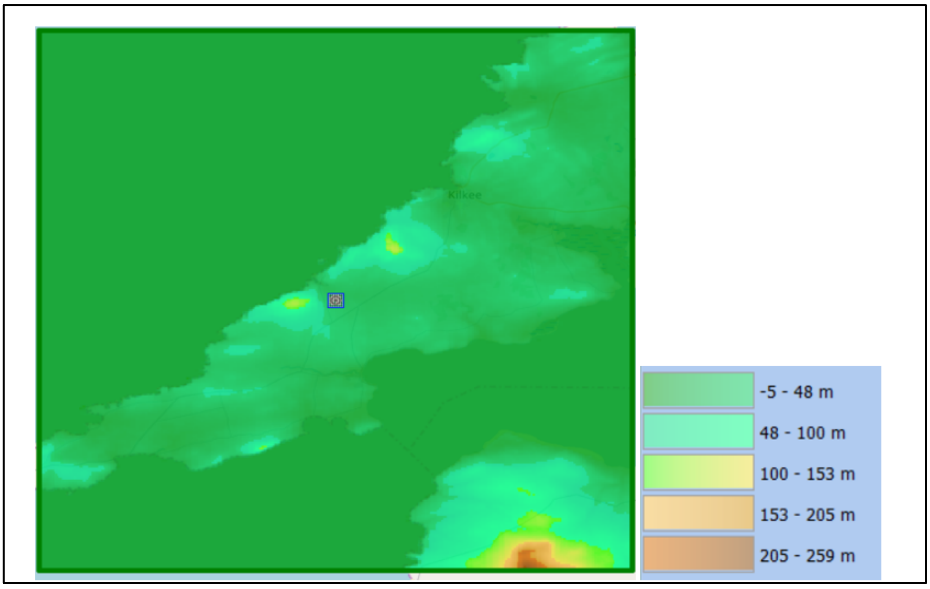
13.6 Appendix 6

Height Contour calculation on WindPRO



13.7 Appendix 7

Elevation data of Loop Head from WindPRO calculation



13.8 Appendix 8

Correlation calculation between short term wind series from 2018 to long term wind series from 1990 to 2019 from WindPRO.

Wind speed observed and standard errors observed are as follows:

Mean Wind Speed at Key Height of 50m (Above ground level) = 7.88 m/s

Mean Wind Speed at Measured Height of 100m (Above ground level) = 9.2 m/s

Correlation in Wind Speed (r) = 0.8792

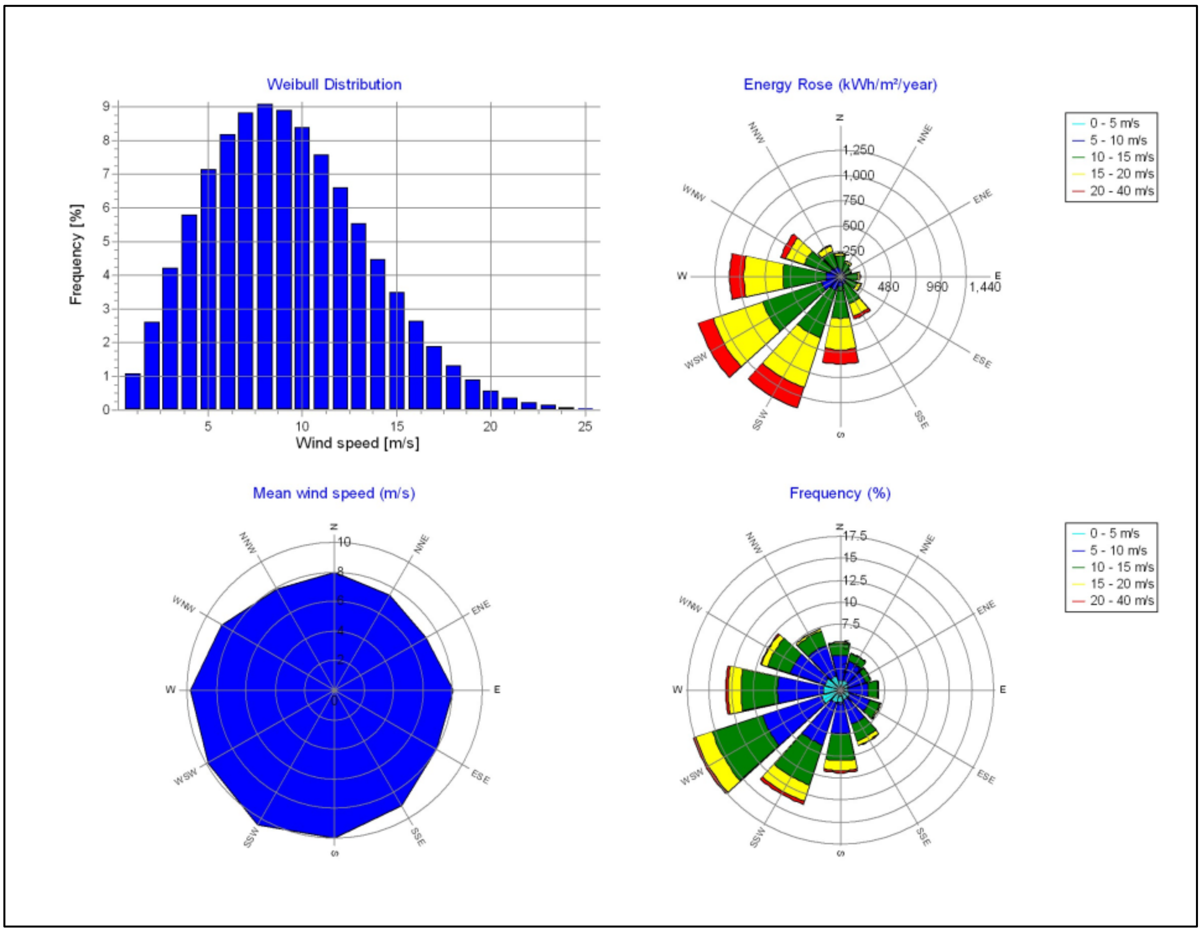
Correlation in Wind Index = 0.9929

Standard Error in Wind Speed = 2.0311 m/s

Standard Error in Wind Index = 3.9355 m/s

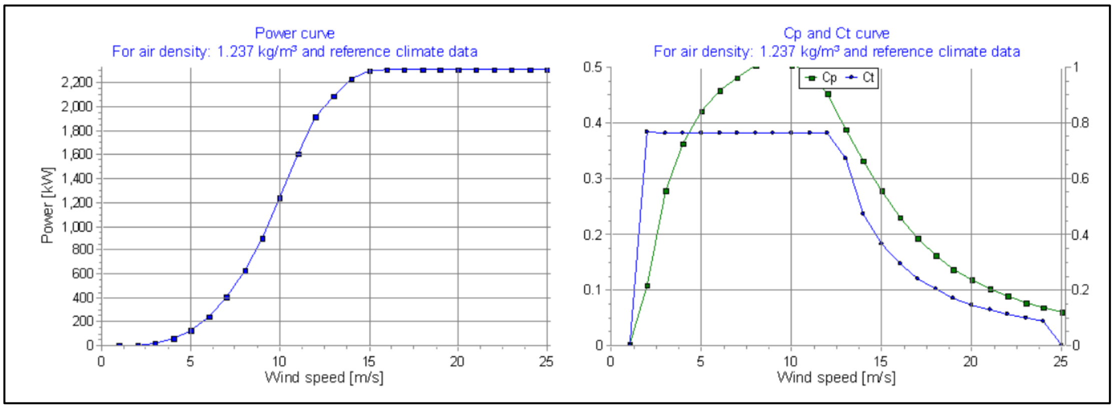
13.9 Appendix 9

Wind statistics calculation at the hub height of 100m in WindPRO



13.10 Appendix 10

Power curve of ENERCON E70, 2.3 MW Wind Turbine



13.11 Appendix 11

Annual energy output from a third wind turbine in an existing wind farm

PARK - Main Result

Calculation: Park with 29 years MCP

Setup
AEP assuming long term representative time series data with optional corrections

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: -0.6°

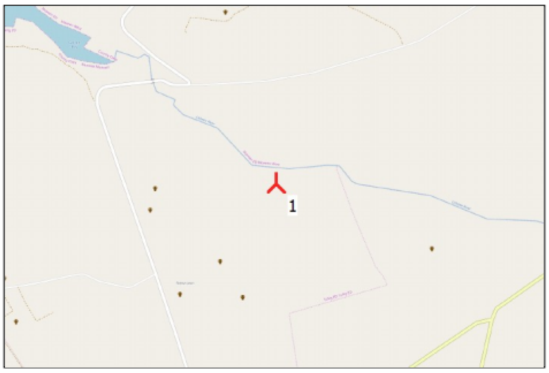
Wake
Wake Model: N.O. Jensen (RISØ/EMD)
Wake decay constant
Wake decay constant: 0.075 DTU default onshore

Scaler/wind data

Name	EMD Default Measurement Mast Scaler
Used period	1/1/1990 - 11/30/2019 11:00:00 PM
Meteo object(s)	Default Meteo data description (24) (Regression MCP using ERA5_N52.693186_W009.450000 (25)), 100.00m -
Displacement height: Omnidirectional from objects	
WAsP version	WAsP 11 Version 11.06.0012

Power correction (All new WTGs)
Power curve correction (adjusted IEC method, improved to match turbine control)

		Min	Max	Avg	Corr. [%]	Neg. corr. [%]	Pos. corr. [%]
Air density							
From air density settings	[°C]	9.6	9.6	9.6			
From air density settings	[hPa]	1003.7	1003.7	1003.7			
Resulting air density	[kg/m³]	1.237	1.237	1.237			
Relative to 15°C at sea level	[%]	100.9	100.9	100.9	0.7	0.0	0.7



Scale 1:25,000

New WTG

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	Result-10.0% [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Specific results¤) Capacity factor [%]	Specific results¤) Mean WTG result [MWh/y]	Specific results¤) Full load hours [Hours/year]	Wind speed free [m/s]	Wind speed wake reduced [m/s]
Wind farm	7,361.2	6,625.1	7,561.0	2.6	32.9	6,625.1	2,880	8.3	8.2

¤) Based on Result-10.0%

Calculated Annual Energy for each of 1 new WTGs with total 2.3 MW rated power

	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh/y]	Result-10.0% [MWh/y]	Wake loss [%]	Wind speed free [m/s]	reduced [m/s]
1	Yes	ENERCON	E-70 E4 2,3 MW-2,300	2,300	71.0	59.0	EMD	Level 0 - guaranteed* - OM II/Rev 1.0 - 05/2005	7,361.2	6,625	2.6	8.31	8.20

WTG siting

	UTM (north)-WGS84 Zone: 29 Easting	Northing	Z [m]	Row data/Description	Calculation period Start	End
1 New	451,016	5,832,235	19.1	ENERCON E-70 E4 2,3 MW 2300 71.0 !O! hub: 59.0 m (TOT: 94.5 m) (8)	1/1/1990	11/30/2019

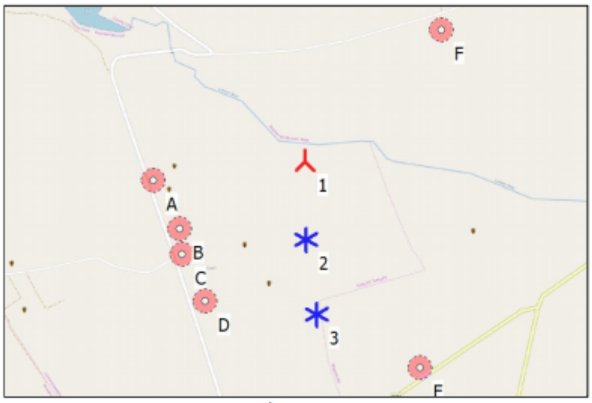
13.12 Appendix 12

Calculation Results Showing Noise Level in 6 Noise Sensitive Areas (A, B, C, D, E and F) showing detailed calculations from WindPRO

DECIBEL - Main Result

Calculation: Noise with MCP: Decibel

Noise calculation model:
ISO 9613-2 General
Wind speed (in 10 m height):
8.0 m/s
Ground attenuation:
Fixed values, Agr: 0.0, Dc: 0.0
Meteorological coefficient, C0:
0.0 dB
Type of demand in calculation:
1: WTG noise is compared to demand (DK, DE, SE, NL etc.)
Noise values in calculation:
All noise values are mean values (Lwa) (Normal)
Pure tones:
Fixed penalty added to source noise of WTGs with pure tones
Model: 5.0 dB(A)
Height above ground level, when no value in NSA object:
0.0 m; Don't allow override of model height with height from NSA object
Uncertainty margin:
0.0 dB; Uncertainty margin in NSA has priority
Deviation from "official" noise demands. Negative is more restrictive, positive is less restrictive.:
0.0 dB(A)



Scale 1:25,000
New WTG   Existing WTG
Noise sensitive area

WTGs

	Longitude	Latitude	Z [m]	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Noise data Creator	Name	Wind speed [m/s]	Status	LwA,ref [dB(A)]	Pure tones
1	-9.723865° E	52.637881° N	19.1	ENERCON E-70 E4 2,3 MW 2...	Yes	ENERCON	E-70 E4 2,3 MW-2,300	2,300	71.0	59.0	EMD	Level 0 - man.spec. - OM II/Rev.1.2 - 04/2012	8.0	User value	102.9	No
2	-9.723783° E	52.635176° N	25.8	ENERCON E-70 E4 2,3 MW 2...	Yes	ENERCON	E-70 E4 2,3 MW-2,300	2,300	71.0	59.0	EMD	Level 0 - man.spec. - OM II/Rev.1.2 - 04/2012	8.0	User value	102.9	No
3	-9.723173° E	52.632556° N	32.6	ENERCON E-70 E4 2,3 MW 2...	Yes	ENERCON	E-70 E4 2,3 MW-2,300	2,300	71.0	59.0	EMD	Level 0 - man.spec. - OM II/Rev.1.2 - 04/2012	8.0	User value	102.9	No

Calculation Results

Sound level

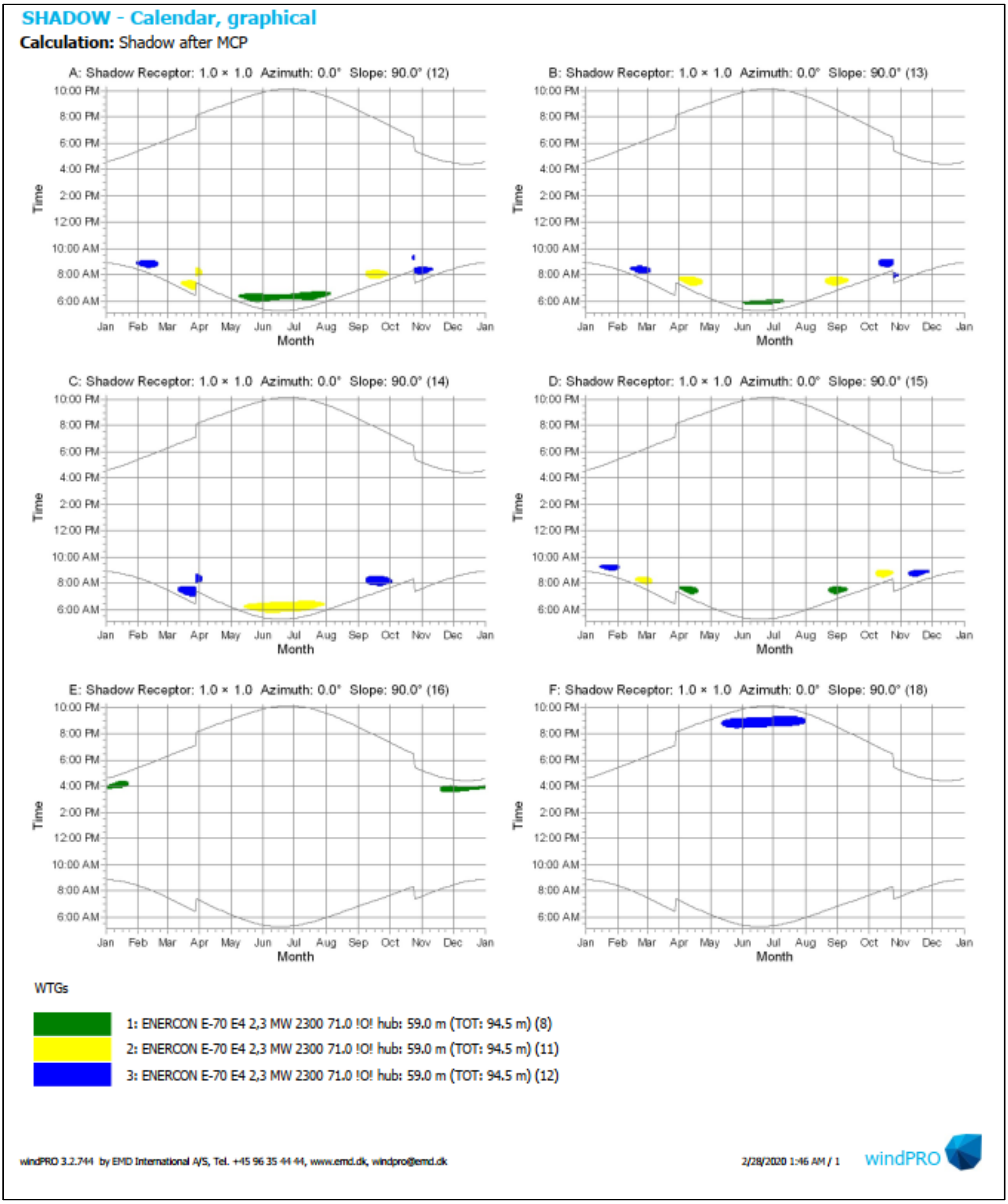
Noise sensitive area No.	Name	Longitude	Latitude	Z [m]	Imission height [m]	Demands Noise [dB(A)]	Sound level From WTGs [dB(A)]	Distance to noise demand [m]	Demands fulfilled ? Noise
A	Noise sensitive point: User defined (5)	-9.732540° E	52.637217° N	33.8	0.0	24.0	39.0	-1,844	**No**
B	Noise sensitive point: User defined (6)	-9.730998° E	52.635549° N	35.8	0.0	24.0	40.9	-1,980	**No**
C	Noise sensitive point: User defined (7)	-9.730888° E	52.634649° N	40.7	0.0	24.0	40.9	-1,985	**No**
D	Noise sensitive point: User defined (8)	-9.729576° E	52.633046° N	39.5	0.0	24.0	41.8	-2,020	**No**
E	Noise sensitive point: User defined (11)	-9.717236° E	52.630719° N	29.7	0.0	24.0	40.0	-1,855	**No**
F	Noise sensitive point: User defined (12)	-9.716034° E	52.642438° N	30.9	0.0	24.0	35.8	-1,561	**No**

Distances (m)

NSA	WTG 1	2	3
A	592	635	819
B	548	490	626
C	596	484	572
D	662	458	437
E	914	665	451
F	733	963	1201

13.13 Appendix 13

Shadow calendar showing shadow flicker experienced by six shadow receptors from three wind turbines in a wind farm over a year.



13.14 Appendix 14

Average standard costs for upgrading building prior to 1919 (TABULA, 2017)

Building Upgrading Measures	Average Standard Costs

1. Roof Upgrading	€	1,606
2. Wall Upgrading (external and internal insulation)	€	17,087
3. Doors and Windows Upgrading	€	7,417
4. Space and Water Heating Upgrading	€	9,682
Total average standard upgrading costs	**€**	**35,792**

13.15 Appendix 15

SEAI grants for individual building retrofit (SEAI, SEAI Community Energy Grant 2020 Application Guidelines, 2020)

Grants Available for Individual Retrofit Works		
S.N.	**Typology**	**Cash Grant Value (€)**
1. Insulation of Wall -Cavity		400
2. Attic Insulation		400
3. Wall-Internal Dry Lining	Mid-Terrace House/ Apartment	1,600
	Semi-Detached or End of Terrace	2,200
	Detached House	2,400
4. Wall- External	Mid-Terrace House/ Apartment	2,750
	Semi-Detached or End of Terrace	4,500
	Detached House	6,000
5. Heating Controls Upgrade		700
6. Solar Thermal		1,200
7. Heat Pumps	1. Air to Water	3,500
	2. Ground Source	3,500
	3. Exhaust Air to Water	3,500
	4. Water to Water	3,500
	5. Air to Air	600

13.16 Appendix 16

Primary Energy Consumptions and Savings in Households Built Pre 1919 (TABULA, 2017)

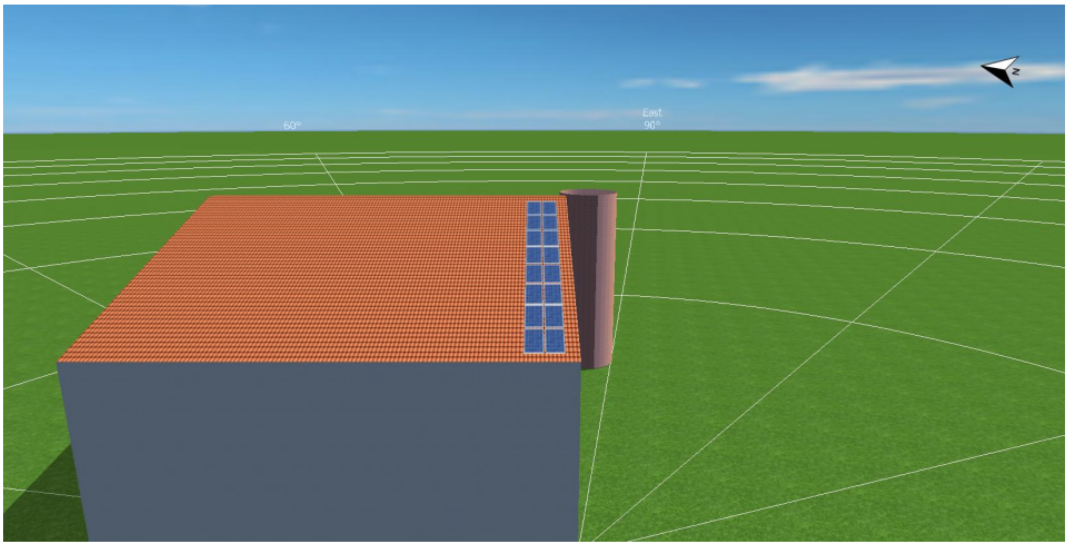
Assuming 1MWh = 134 Litres of Oil

Total Primary Energy Consumption Bungalow Solid Walls Pre 1919 (kWh/m^2/year)	312
Area of Building (m2)	82
Total Primary Energy after Roof Upgrading (kWh/m^2/year)	261
Total Primary Energy after Wall Upgrading (kWh/m^2/year)	185
Total primary energy savings after Roof and Wall Upgrading (kWh/m^2/year)	127
Total Savings in Heating Oil per Household (litres/year)	1395

13.17 Appendix 17

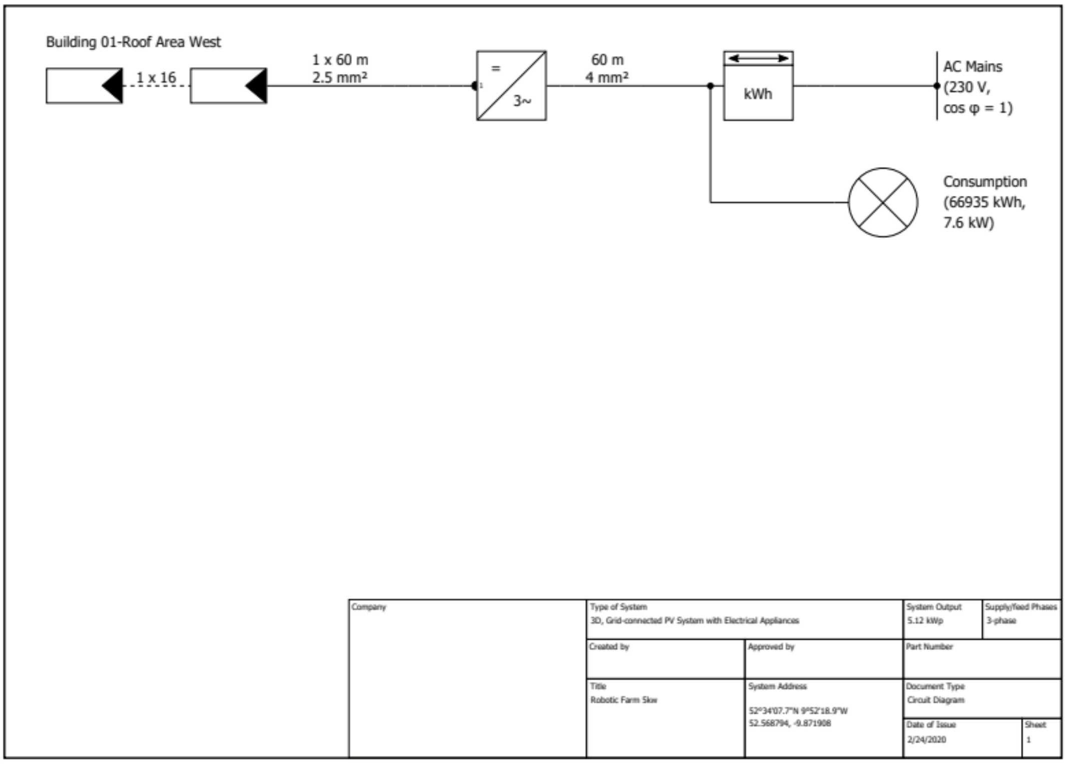
Results scenario 1: PV Generator Output 5.2KWp

System planning with 3D visualization



Number of Covered Areas	1
Number of PV Modules	16
Number of Inverters	1
PV Generator Output	5.12 kWp

Circuit Diagram



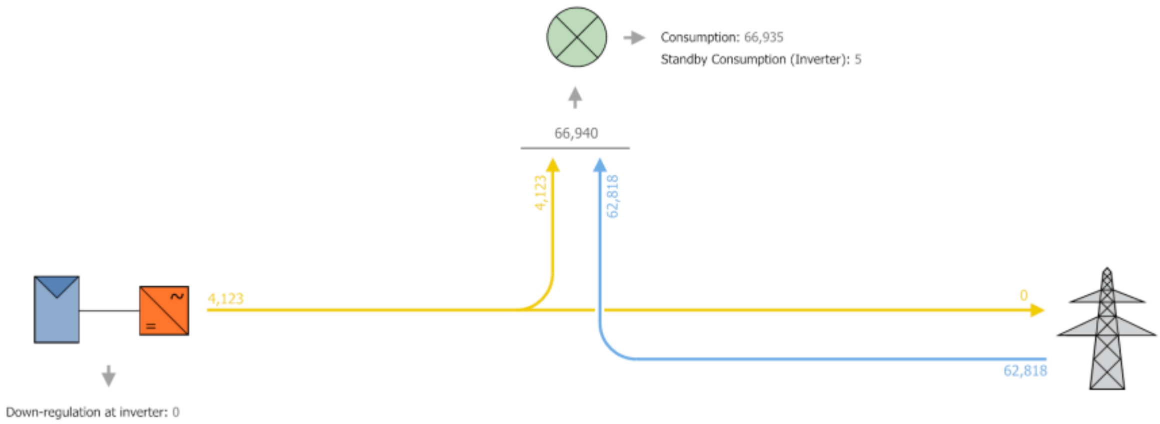
Part list used

Type	Manufacturer	Name	Quantity	Unit
PV Module	**Canadian Solar Inc.**	**CS6U-320P**	**16**	**Piece**
Inverter	Samil Power Co., Ltd.	SolarLake 5500TL-PM	1	Piece
Meter		Bidirectional Meter	1	Piece
Cable		String Cable 2.5 mm² Copper	60	m
Cable		AC Cable 3-phase 4 mm² Copper	60	m

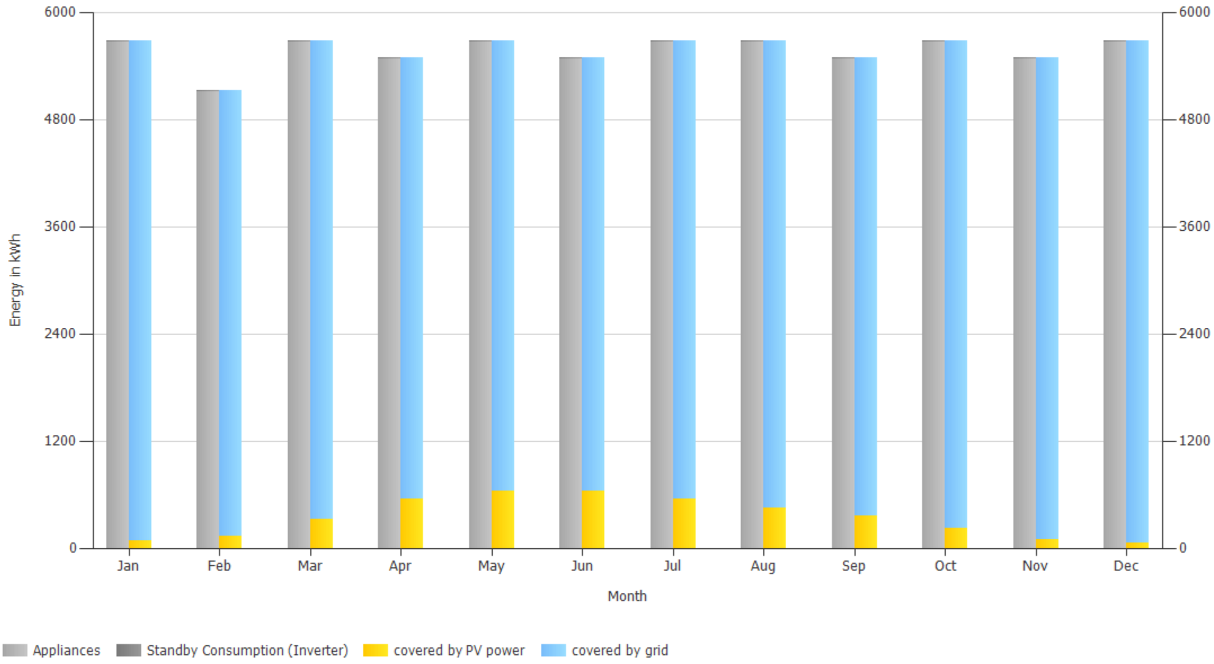
Simulation overview results

PV System		
PV Generator Output	5.1	kWp
Spec. Annual Yield	805.25	kWh/kWp
Performance Ratio (PR)	87.4	%
Yield Reduction due to Shading	0.0	%/Year
PV Generator Energy (AC grid)	4,123	kWh/Year
Own Consumption	4,123	kWh/Year
Grid Feed-in	0	kWh/Year
Down-regulation at Feed-in Point	0	kWh/Year
Own Power Consumption	100.0	%
CO_2 Emissions avoided	1,938	kg / year
Appliances		
Appliances	66,935	kWh/Year
Standby Consumption (Inverter)	5	kWh/Year
Total Consumption	66,940	kWh/Year
covered by PV power	4,123	kWh/Year
covered by grid	62,818	kWh/Year
Solar Fraction	6.2	%

Energy flow graph

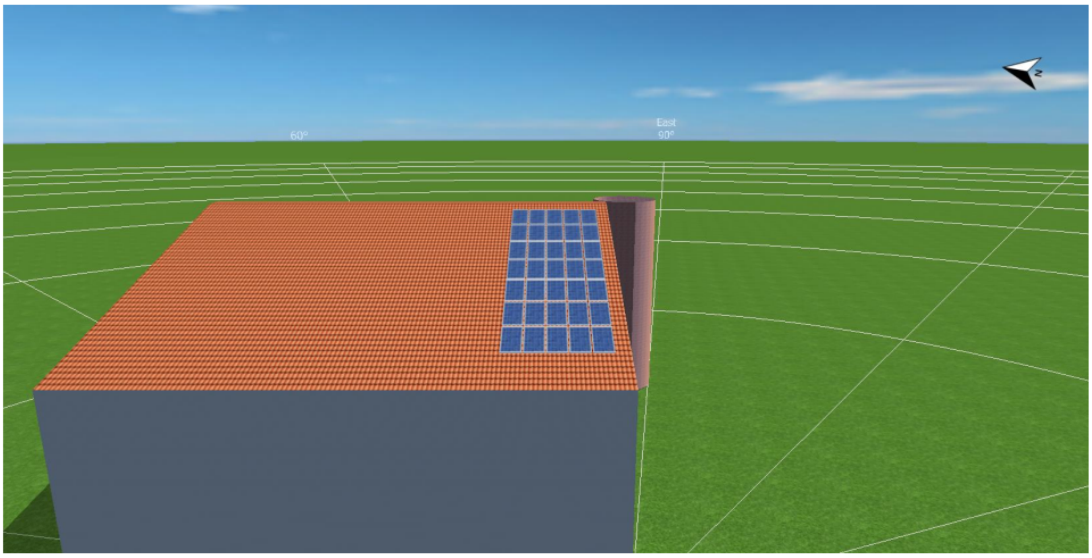


Coverage of consumption



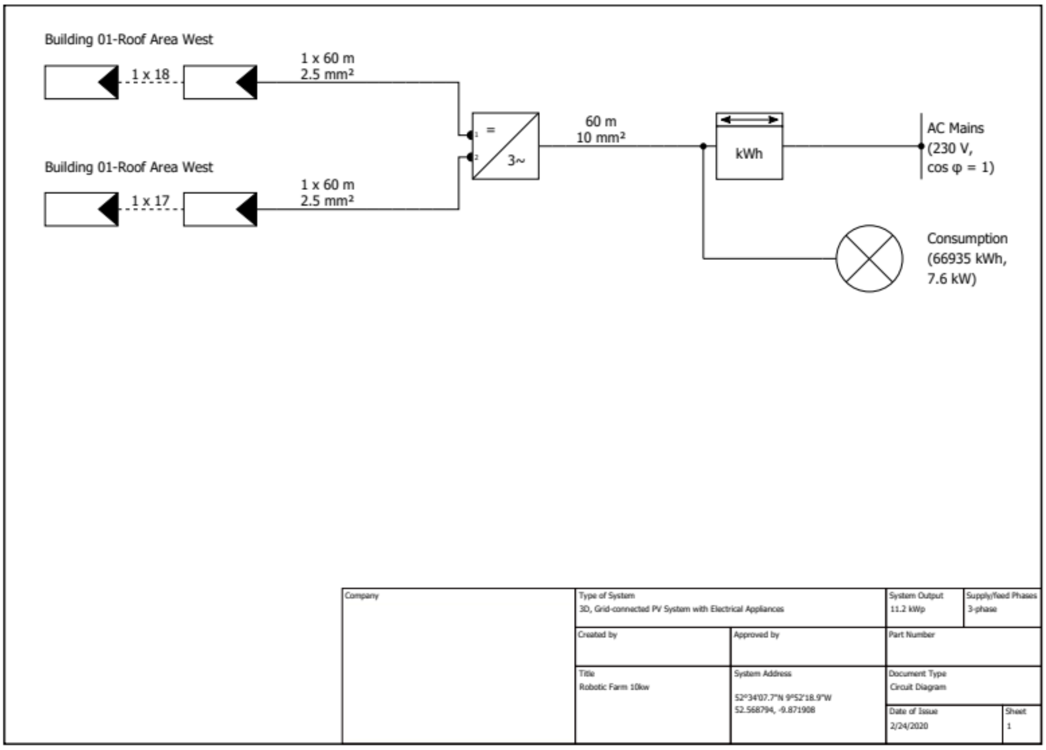
Results scenario 2: PV Generator Output 11.2KWp

System Planning with 3D visualization



Number of Covered Areas	1
Number of PV Modules	35
Number of Inverters	1
PV Generator Output	11.2 kWp

Circuit Diagram



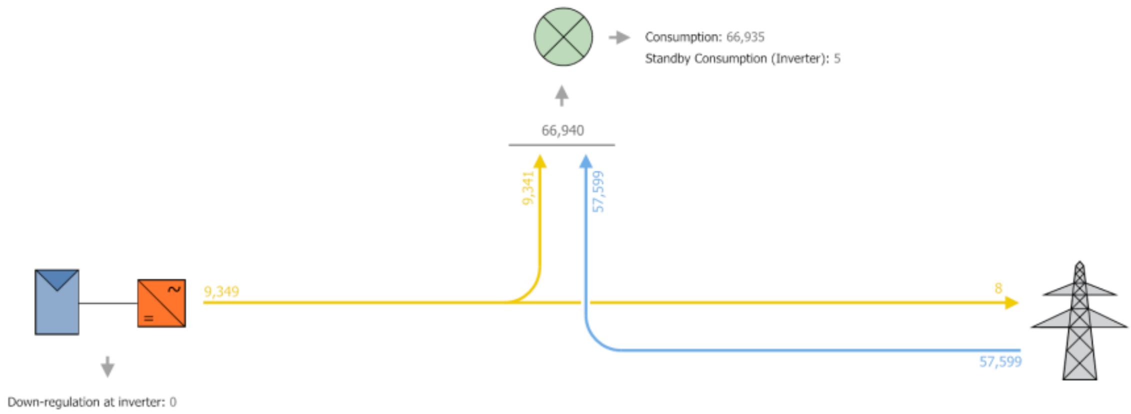
Part list used

Type	Manufacturer	Name	Quantity	Unit
PV Module	**Canadian Solar Inc.**	**CS6U-320P**	**35**	**Piece**
Inverter	Samil Power Co., Ltd.	SolarLake 12000TL-PM	1	Piece
Meter		Bidirectional Meter	1	Piece
Cable		AC Cable 3-phase 10 mm² Copper	60	m
Cable		String Cable 2.5 mm² Copper	120	m

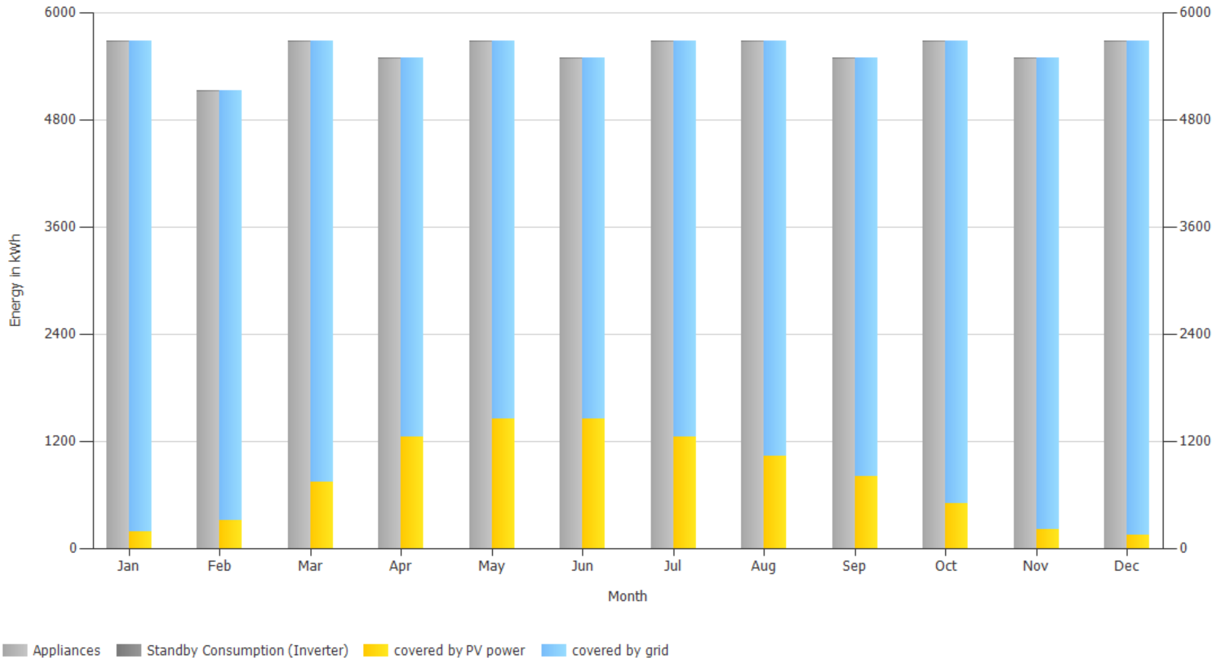
Simulation overview results

PV System	
PV Generator Output	11.2 kWp
Spec. Annual Yield	834.73 kWh/kWp
Performance Ratio (PR)	90.6 %
Yield Reduction due to Shading	0.0 %/Year
PV Generator Energy (AC grid)	9,349 kWh/Year
Own Consumption	9,341 kWh/Year
Grid Feed-in	8 kWh/Year
Down-regulation at Feed-in Point	0 kWh/Year
Own Power Consumption	99.9 %
CO_2 Emissions avoided	4,394 kg / year
Appliances	
Appliances	66,935 kWh/Year
Standby Consumption (Inverter)	5 kWh/Year
Total Consumption	66,940 kWh/Year
covered by PV power	9,341 kWh/Year
covered by grid	57,599 kWh/Year
Solar Fraction	14.0 %

Energy flow graph

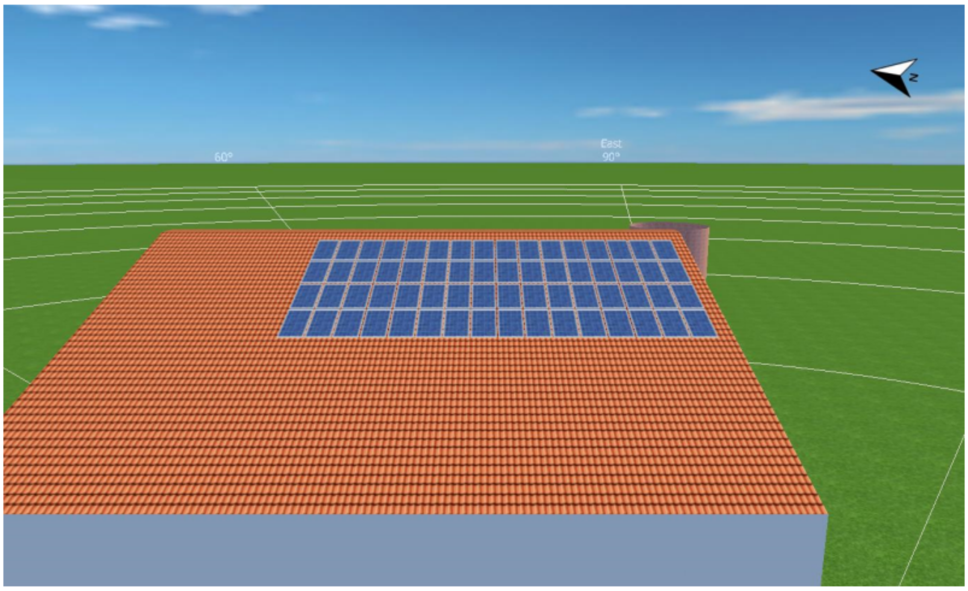


Coverage of consumption



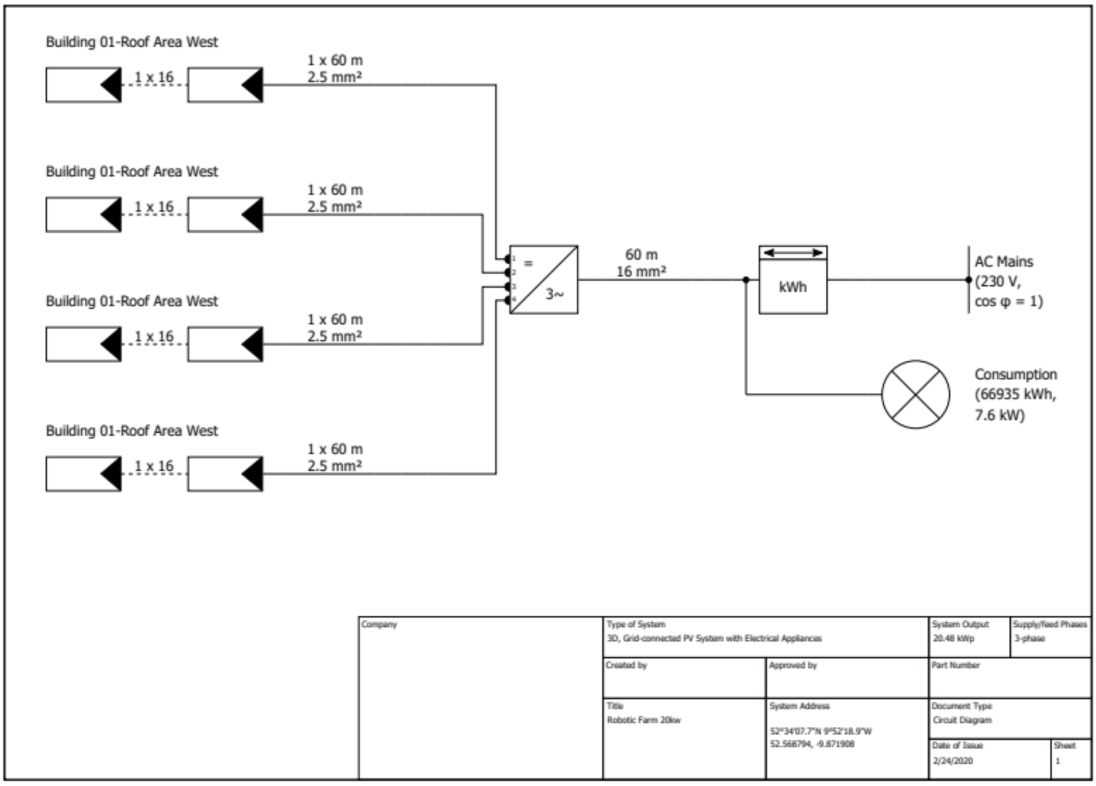
Results scenario 3: PV Generator Output 20.5KWp

System Planning with 3D visualization



Number of Covered Areas	1
Number of PV Modules	64
Number of Inverters	1
PV Generator Output	20.48 kWp

Circuit diagram



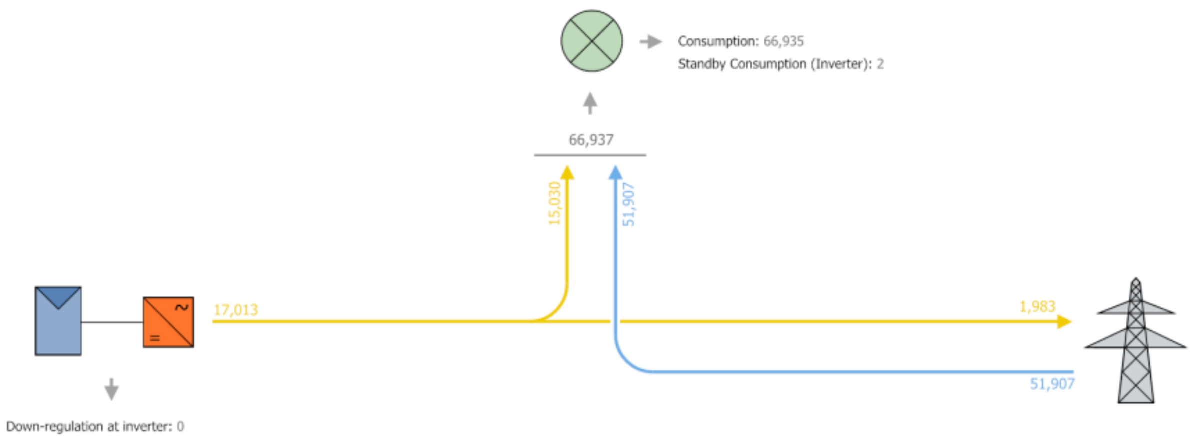
Part list used

Type	Manufacturer	Name	Quantity	Unit
PV Module	Canadian Solar Inc.	CS6U-320P	64	Piece
Inverter	Canadian Solar Inc.	CSI-20KTL-GI-FL	1	Piece
Meter		Bidirectional Meter	1	Piece
Cable		AC Cable 3-phase 16 mm² Copper	60	m
Cable		String Cable 2.5 mm² Copper	240	m

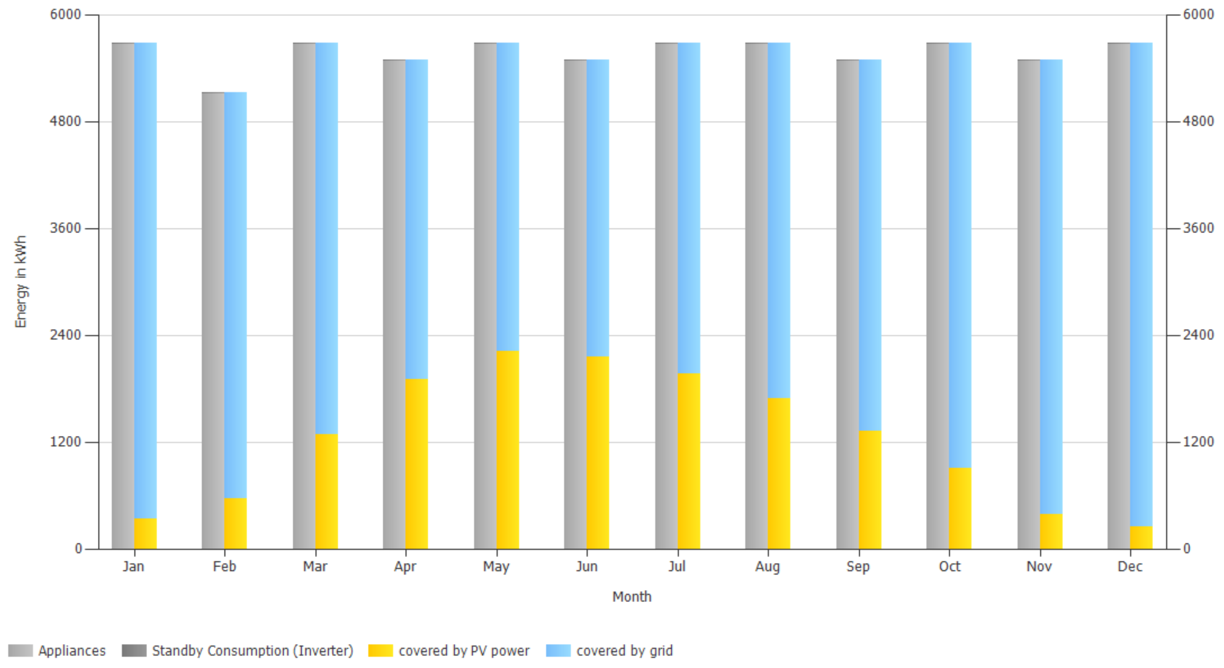
Simulation overview results

PV System		
PV Generator Output	20.5	kWp
Spec. Annual Yield	830.74	kWh/kWp
Performance Ratio (PR)	90.2	%
Yield Reduction due to Shading	0.0	%/Year
PV Generator Energy (AC grid)	17,013	kWh/Year
Own Consumption	15,030	kWh/Year
Grid Feed-in	1,983	kWh/Year
Down-regulation at Feed-in Point	0	kWh/Year
Own Power Consumption	88.3	%
CO_2 Emissions avoided	7,996	kg / year
Appliances		
Appliances	66,935	kWh/Year
Standby Consumption (Inverter)	2	kWh/Year
Total Consumption	66,937	kWh/Year
covered by PV power	15,030	kWh/Year
covered by grid	51,907	kWh/Year
Solar Fraction	22.5	%

Energy flow graph

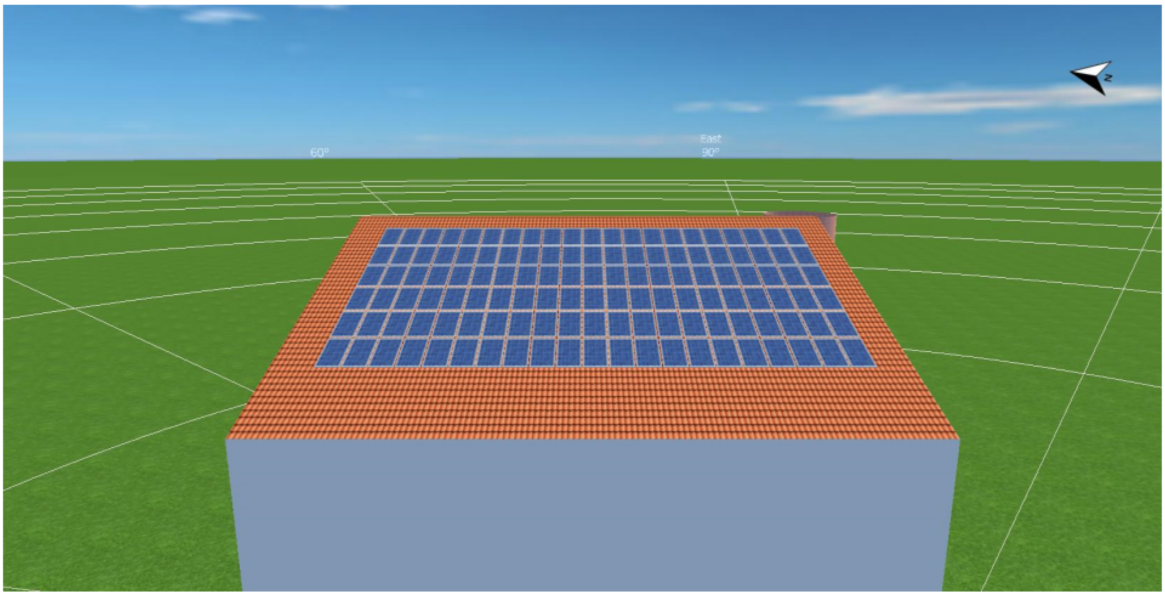


Coverage of consumption



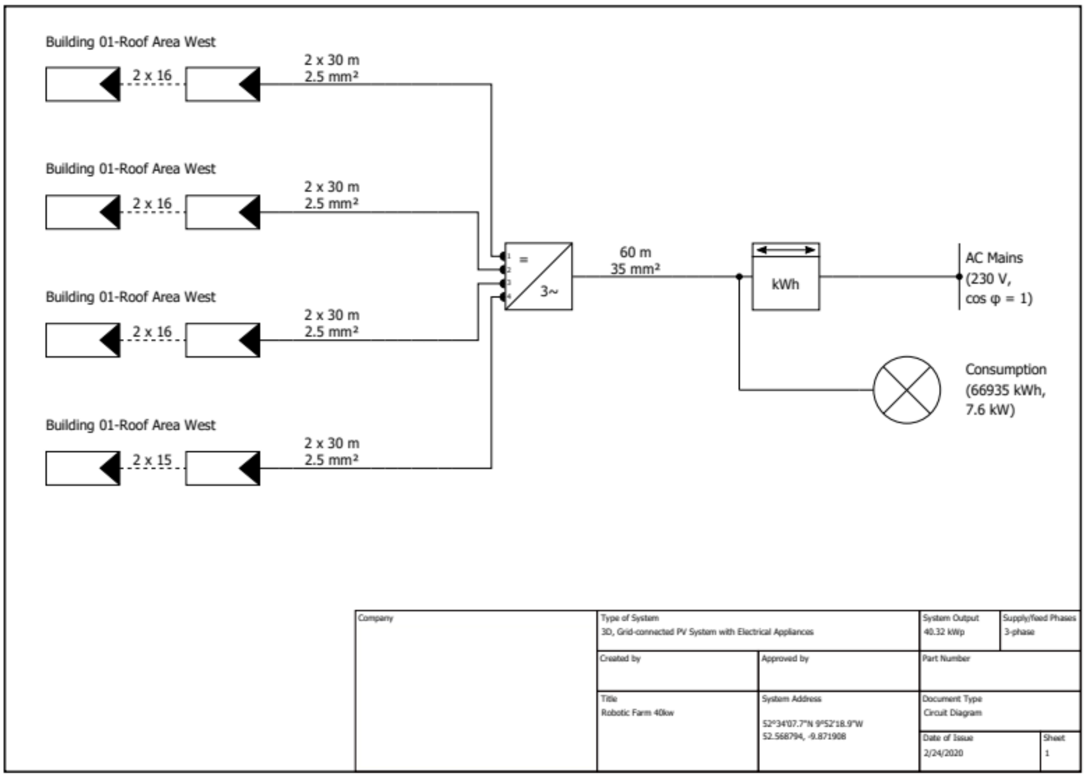
Results scenario 4: PV Generator Output 40.32KWp

System Planning with 3D visualization



Number of Covered Areas	1
Number of PV Modules	126
Number of Inverters	1
PV Generator Output	40.32 kWp

Circuit Diagram



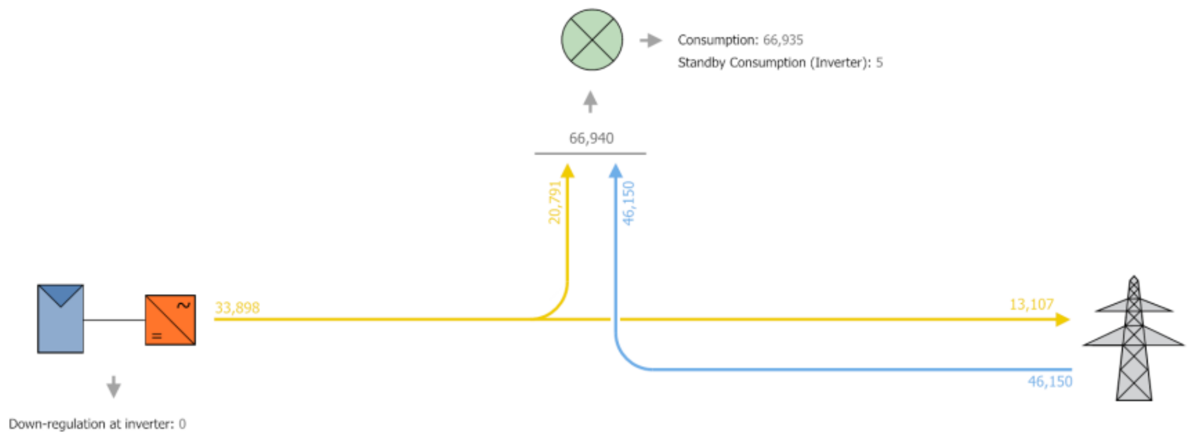
Part list used

Type	Manufacturer	Name	Quantity	Unit
PV Module	**Canadian Solar Inc.**	**CS6U-320P**	**126**	**Piece**
Inverter	Canadian Solar Inc.	CSI-40KTL-GI-FL	1	Piece
Meter		Bidirectional Meter	1	Piece
Cable		String Cable 2.5 mm² Copper	240	m
Cable		AC Cable 3-phase 35 mm² Copper	60	m

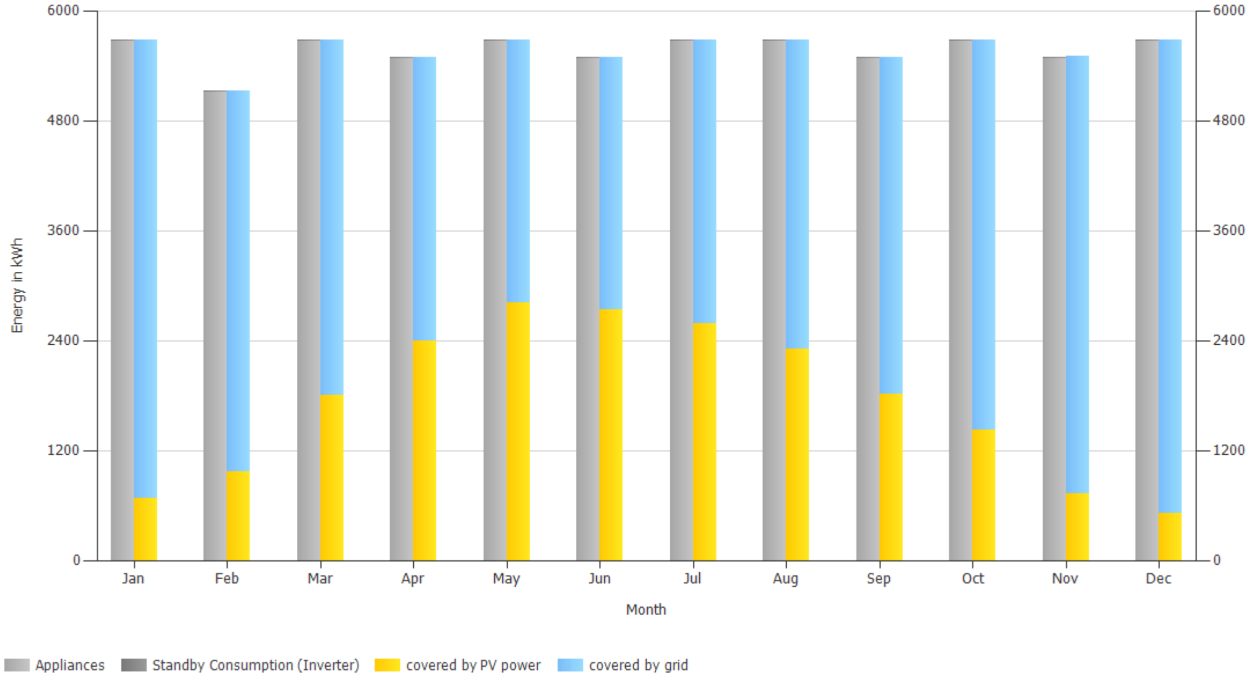
Simulation overview results

PV System	
PV Generator Output	40.3 kWp
Spec. Annual Yield	840.73 kWh/kWp
Performance Ratio (PR)	91.2 %
Yield Reduction due to Shading	0.0 %/Year
PV Generator Energy (AC grid)	33,898 kWh/Year
Own Consumption	20,791 kWh/Year
Grid Feed-in	13,107 kWh/Year
Down-regulation at Feed-in Point	0 kWh/Year
Own Power Consumption	61.3 %
CO_2 Emissions avoided	15,932 kg / year
Appliances	
Appliances	66,935 kWh/Year
Standby Consumption (Inverter)	5 kWh/Year
Total Consumption	66,940 kWh/Year
covered by PV power	20,791 kWh/Year
covered by grid	46,150 kWh/Year
Solar Fraction	31.1 %

Energy flow graph

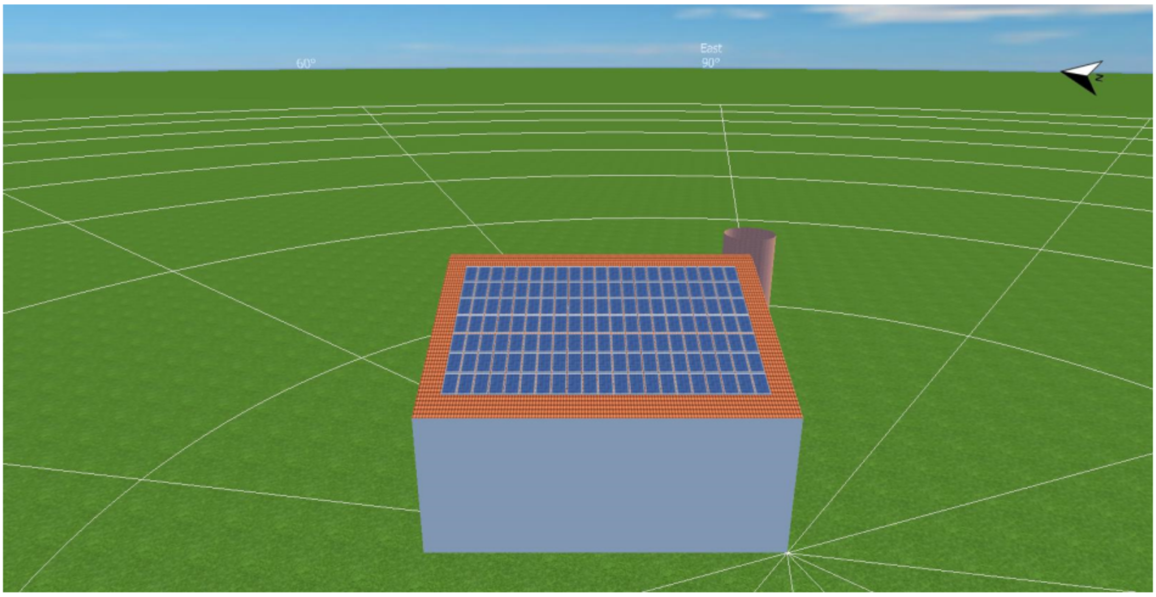


Coverage of consumption

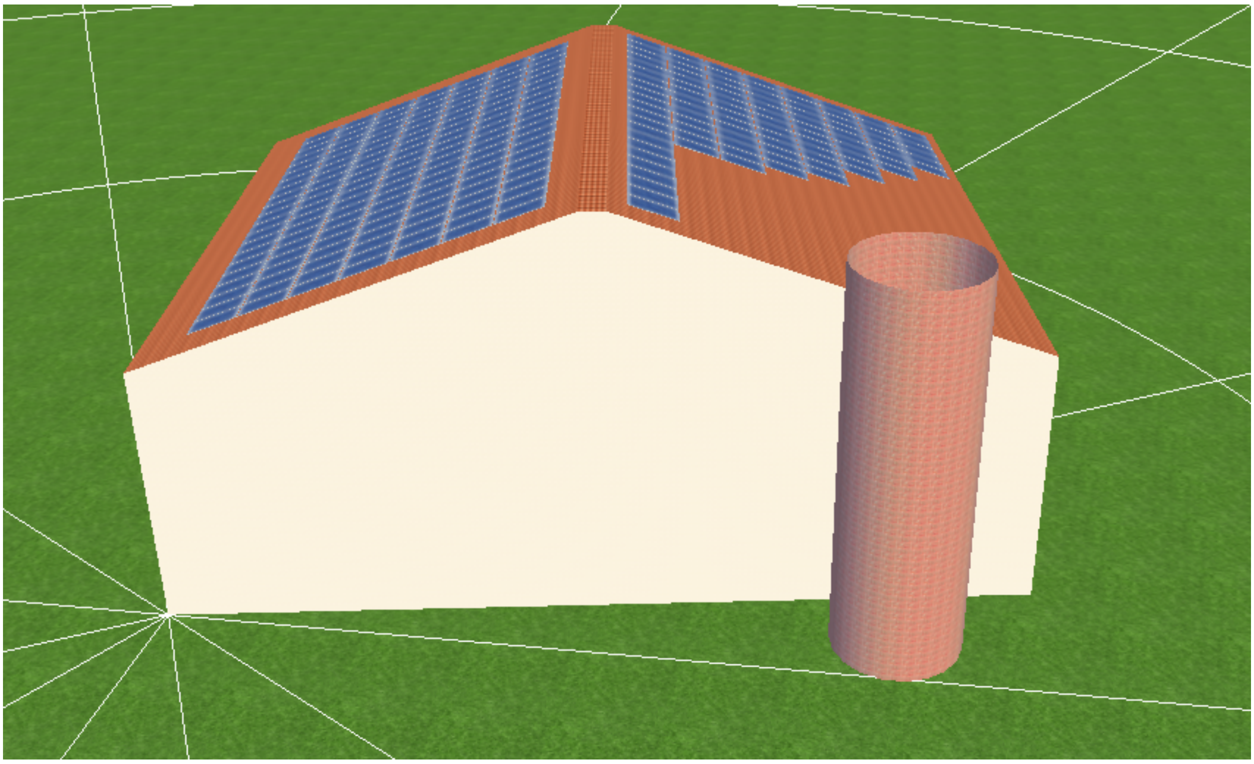


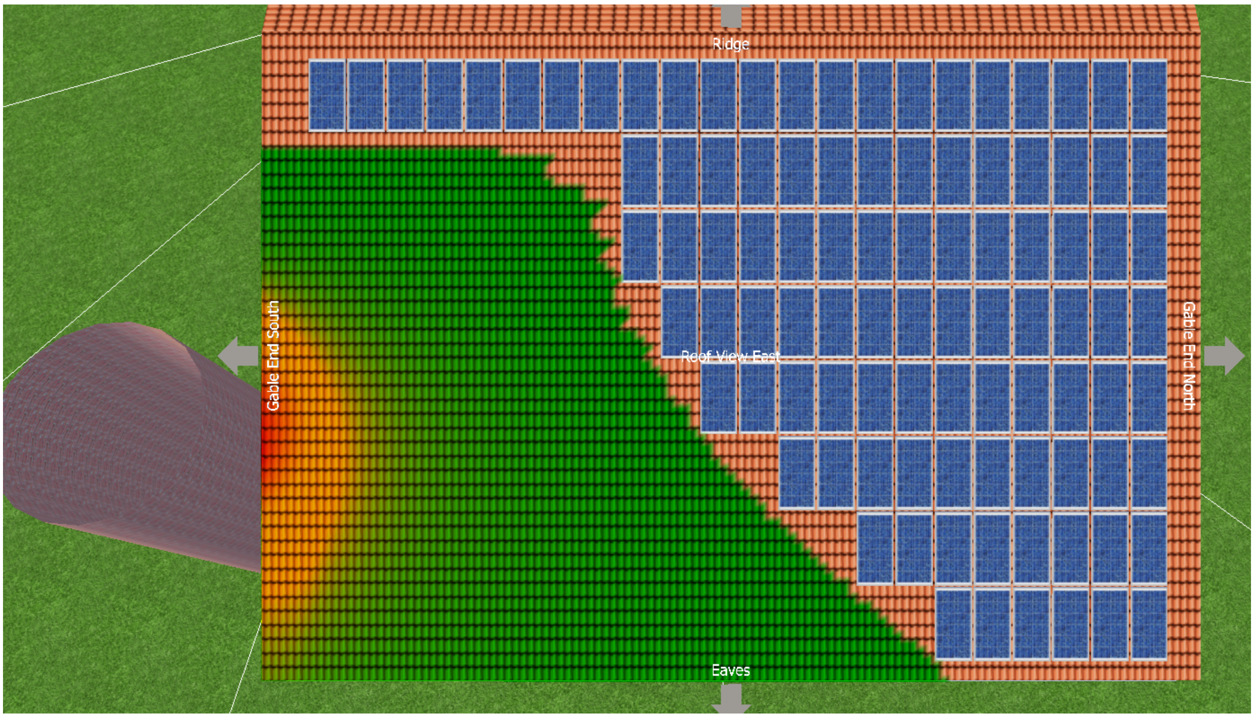
Results scenario 5: PV Generator Output 78.7KWp

System Planning with 3D visualization

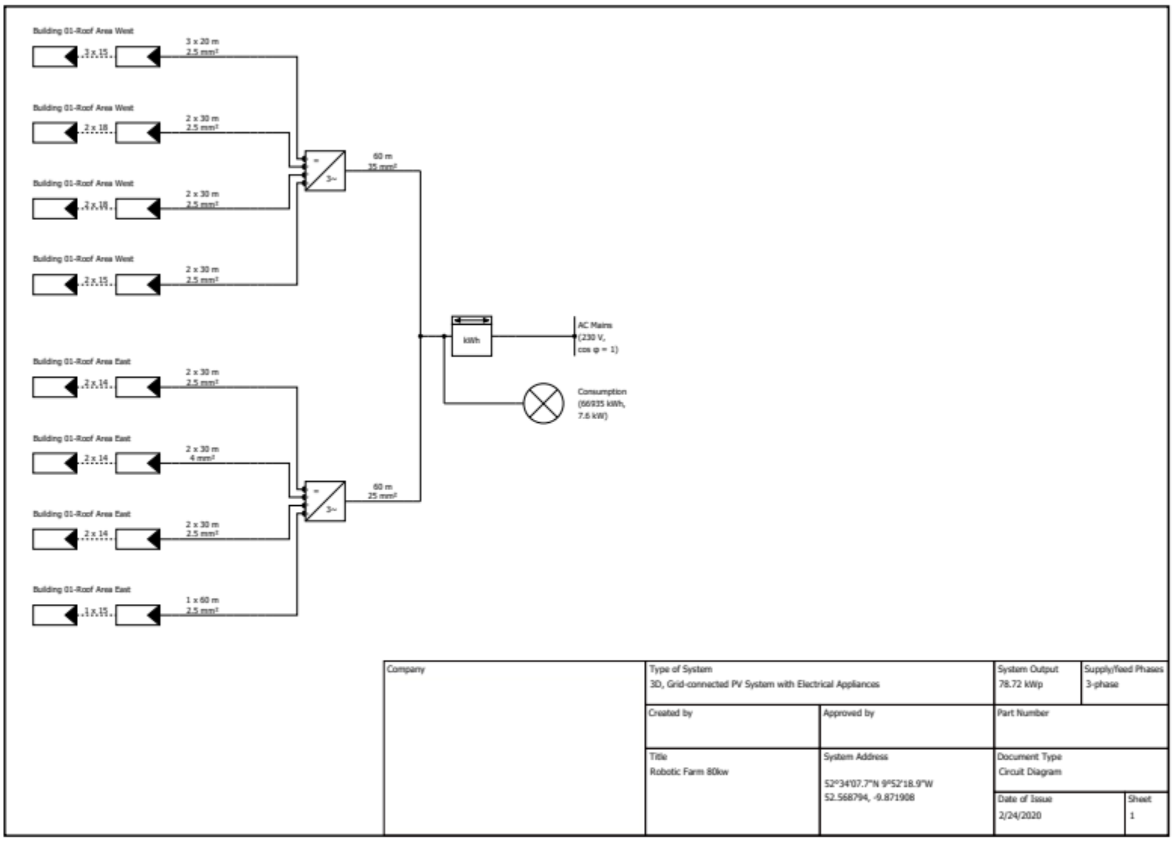


Number of Covered Areas	2
Number of PV Modules	246
Number of Inverters	2
PV Generator Output	78.72 kWp





Circuit Diagram



Part list used

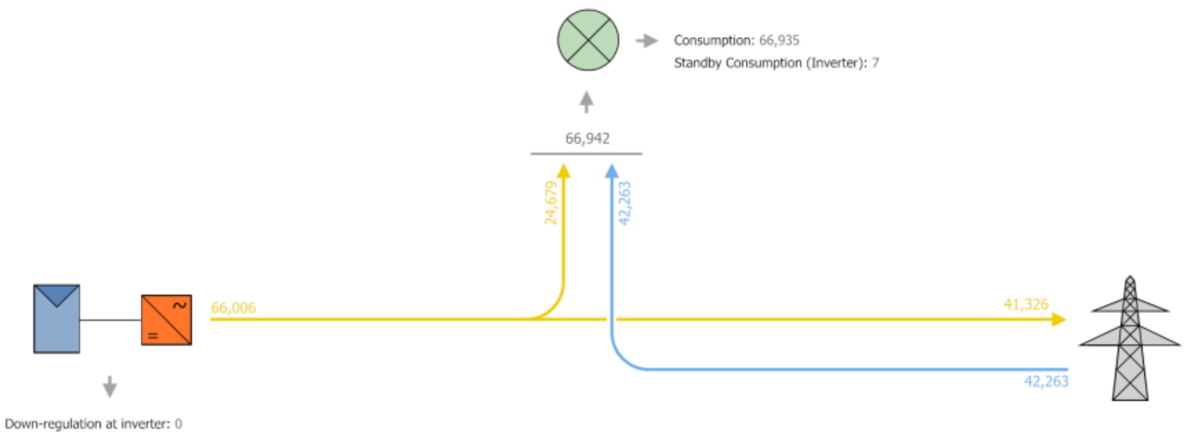
Type	Manufacturer	Name	Quantity	Unit
PV Module	Canadian Solar Inc.	CS6U-320P	246	Piece
Inverter	Canadian Solar Inc.	CSI-50KTL-GI	1	Piece
Inverter	Canadian Solar Inc.	CSI-30KTL-GI-FL	1	Piece
Meter		Bidirectional Meter	1	Piece
Cable		String Cable 2.5 mm² Copper	420	m
Cable		AC Cable 3-phase 25 mm² Copper	60	m
Cable		AC Cable 3-phase 35 mm² Copper	60	m

Cable		String Cable 4 mm² Copper	60	m

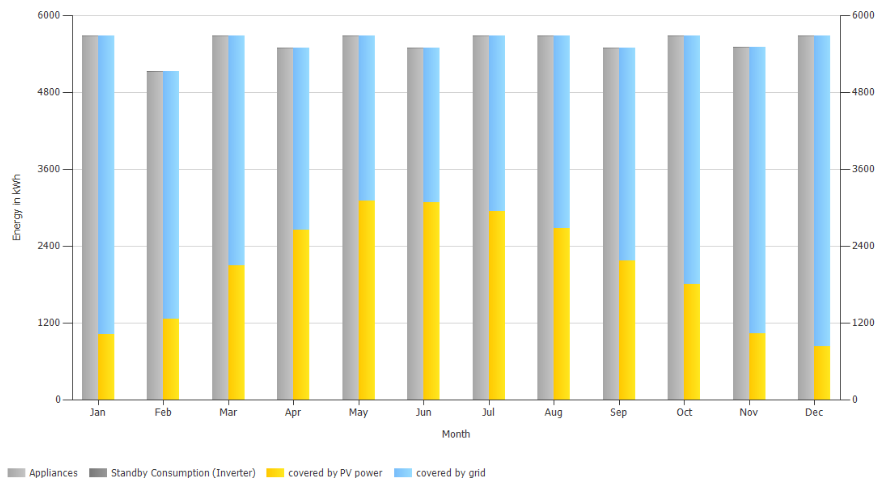
Simulation overview results

PV System		
PV Generator Output	78.7	kWp
Spec. Annual Yield	838.49	kWh/kWp
Performance Ratio (PR)	90.5	%
Yield Reduction due to Shading	0.2	%/Year
PV Generator Energy (AC grid)	66,006	kWh/Year
Own Consumption	24,679	kWh/Year
Grid Feed-in	41,326	kWh/Year
Down-regulation at Feed-in Point	0	kWh/Year
Own Power Consumption	37.4	%
CO_2 Emissions avoided	31,023	kg / year
Appliances		
Appliances	66,935	kWh/Year
Standby Consumption (Inverter)	7	kWh/Year
Total Consumption	66,942	kWh/Year
covered by PV power	24,679	kWh/Year
covered by grid	42,263	kWh/Year
Solar Fraction	36.9	%

Energy flow graph

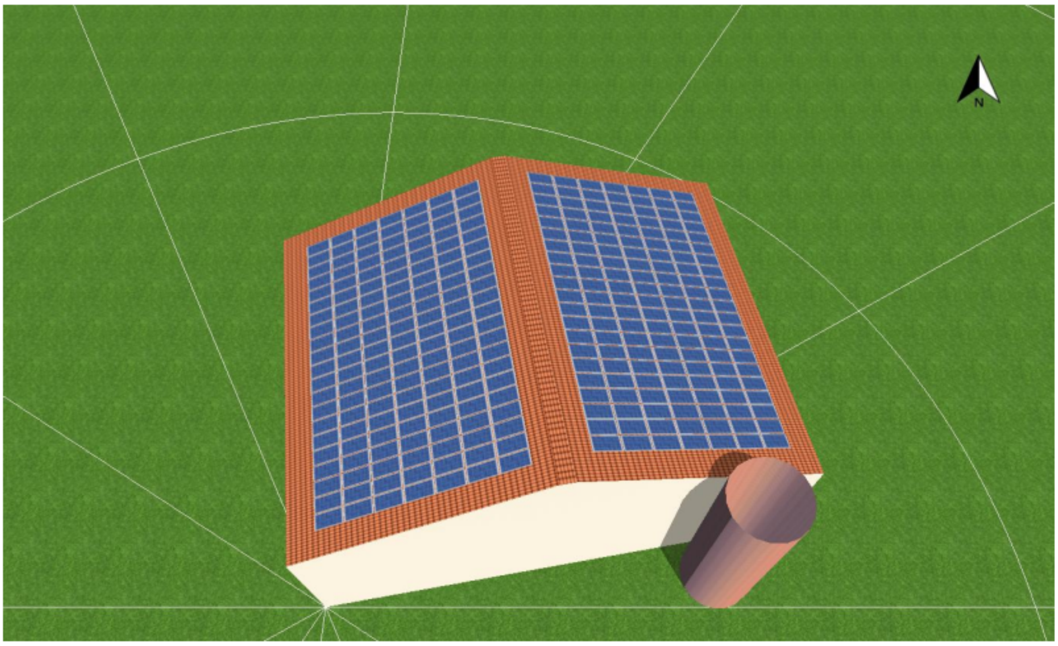


Coverage of consumption



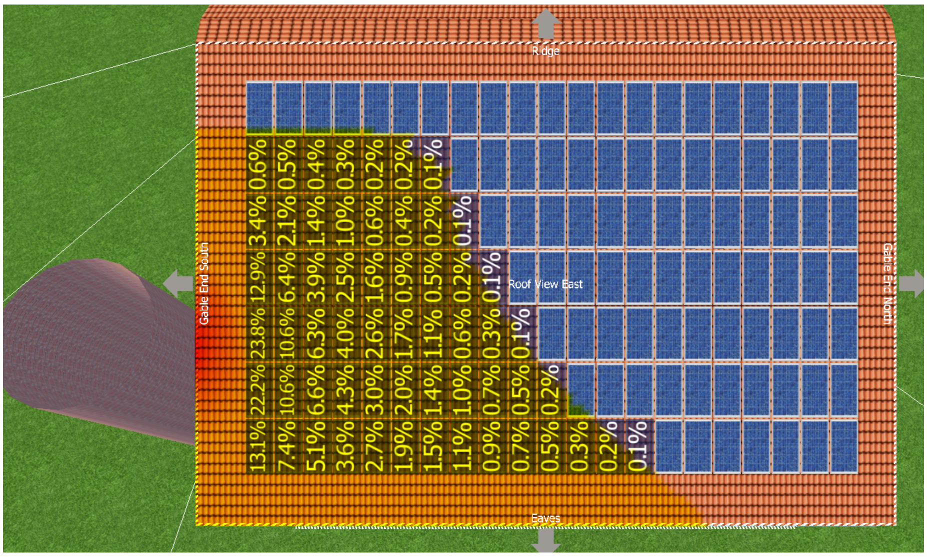
Results scenario 6: PV Generator Output 94.1KWp

System Planning with 3D visualization

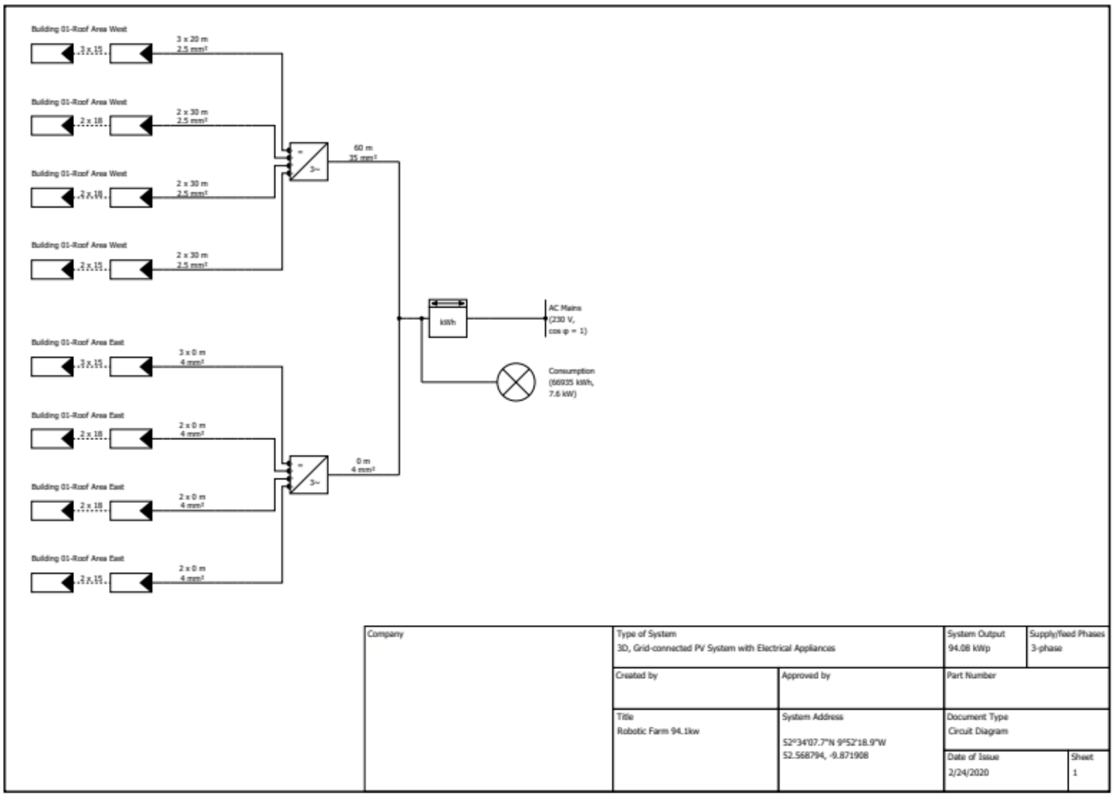


Number of Covered Areas	2
Number of PV Modules	294
Number of Inverters	2
PV Generator Output	94.08 kWp

Shade frequency



Circuit Diagram



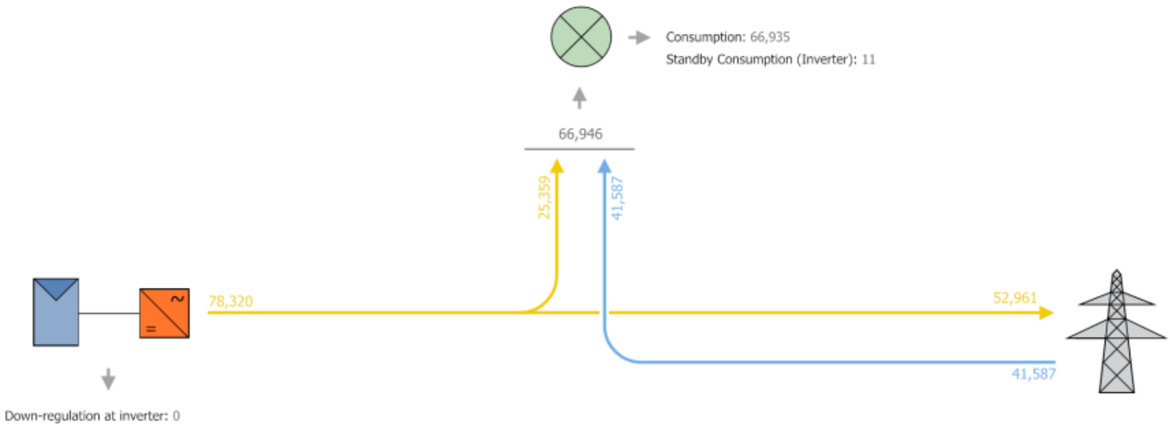
Part list used

Type	Manufacturer	Name	Quantity	Unit
PV Module	Canadian Solar Inc.	CS6U-320P	294	Piece
Inverter	Canadian Solar Inc.	CSI-50KTL-GI	2	Piece
Meter		Bidirectional Meter	1	Piece
Cable		String Cable 2.5 mm² Copper	240	m
Cable		AC Cable 3-phase 35 mm² Copper	60	m

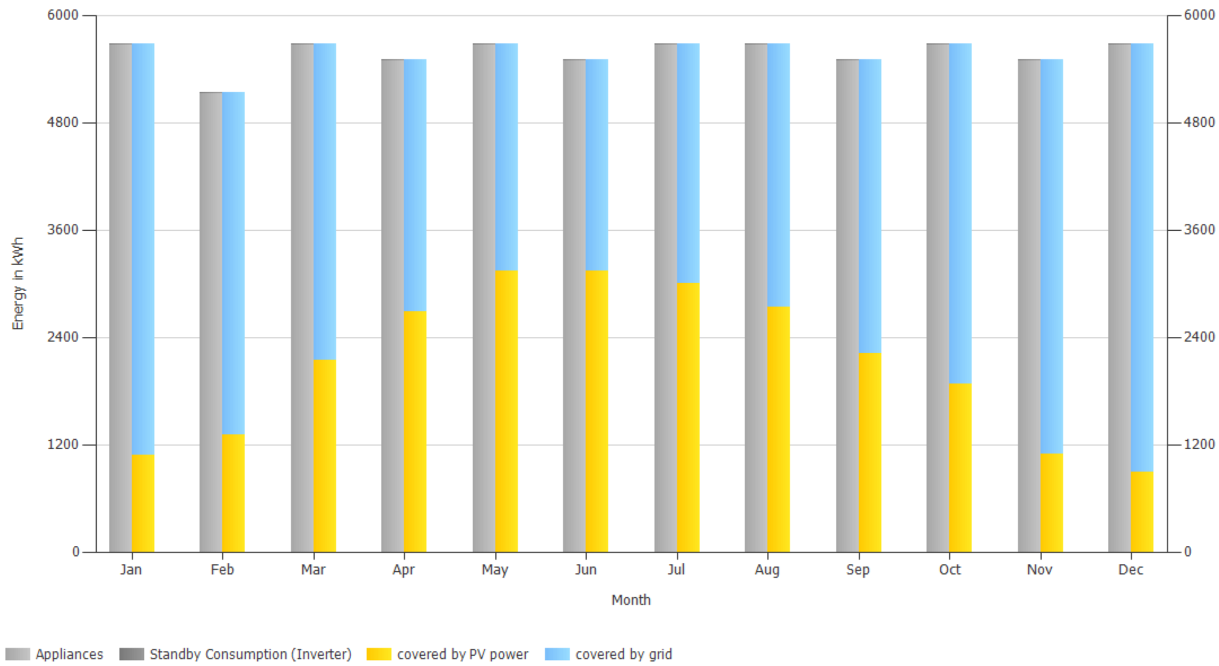
Simulation overview results

PV System		
PV Generator Output	94.1	kWp
Spec. Annual Yield	832.48	kWh/kWp
Performance Ratio (PR)	89.7	%
Yield Reduction due to Shading	1.4	%/Year
PV Generator Energy (AC grid)	78,320	kWh/Year
Own Consumption	25,359	kWh/Year
Grid Feed-in	52,961	kWh/Year
Down-regulation at Feed-in Point	0	kWh/Year
Own Power Consumption	32.4	%
CO_2 Emissions avoided	36,810	kg / year
Appliances		
Appliances	66,935	kWh/Year
Standby Consumption (Inverter)	11	kWh/Year
Total Consumption	66,946	kWh/Year
covered by PV power	25,359	kWh/Year
covered by grid	41,587	kWh/Year
Solar Fraction	37.9	%

Energy flow graph



Coverage of consumption



13.18 Appendix 18

Heating technology information and fuel price used for calculation

Technology	Efficiency	Investment cost (Euros/KW)	Fuel consumption	Fixed O&M	Addition cost (Euros/Unit)
GSHP	325%	3041.7	Electricity	291	0
Heat pump, Air-to-air	450%	1400	Electricity	170	0
Biomass boiler	83%	981.0	Pellets	320	0
District heating from AD plant	100%	0	District heating	0	10000
Heat pump, Air-to-water	325%	1750	Electricity	0	0
Electric boiler	100%	1000	Electricity	25	0

Fuel type	Price	Unit
Electricity	0.2297	euros/kWh
Electricity (Commercial)	0.1399	euros/kWh
LPG	0.113	euros/kWh
District heating	0.12	euros/kWh
Coal price	0.0574	euros/kWh
Kerosene	0.0741	euros/kWh
Pellets	0.0733	euros/kWh

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