



Sustainable Energy Transition Pathway for the Aran Islands

International Class 2025

Hosted by:



**Fuinneamh
Oileáin Árann**
Aran Islands Energy

Funded by:



Deutscher Akademischer Austauschdienst
German Academic Exchange Service

Authored by:

Agus Samsudin
Ama Adadzewaa Essandoh
Amir Hossein Rashvand
Asiya Faiyaz
Busingye Bakwata
Chrisantus Ogeto Omari
Elhamuddin Ragheb
Harriet Patricia Nakanwagi
Muhammad Hassnain
Oscar Adolfo Steiger
Rana Mosaad Refaat Hamed Ahmed
Rubby Melissa Lasso Muñoz
Sainsanaa Amarsanaa
Sajid Ur Rahman
Samiul Huq

Supervised by:

Prof. Dr. Bernd Möller
ASM Mominul Hasan
Nafiseh Mirzakhani

Funded by:

Deutscher Akademischer Austauschdienst (DAAD), Germany

In cooperation with:

Aran Islands Energy Cooperative

Submitted on: 28th February 2025

Disclaimer

This document was prepared by the students of the department of Energy and Environmental Management programme of Europa-Universität Flensburg, Germany, as part of the course named *International Class*, and is intended for informational and academic purposes only. The findings, analyses, and recommendations presented are based on available data, assumptions, and modelling approaches at the time of the study. While every effort has been made to ensure accuracy, the report may contain errors or omissions, and the scenarios and projections presented are hypothetical and subject to change due to external factors, including technological advancements, policy changes, and economic conditions.

The report does not constitute professional, financial, or legal advice, and any decisions made based on its contents are the sole responsibility of the reader. Neither the authors, Europa-Universität Flensburg, nor any affiliated institutions or stakeholders assume liability for any direct or indirect consequences arising from the use of this report. Stakeholders and decision-makers are encouraged to conduct further research and consult professionals before implementing any recommendations.

Table of Contents

Executive Summary	10
1 Introduction.....	11
1.1 Objectives.....	13
1.2 Community engagement.....	13
1.3 General assumptions	14
2 Demand assessment	15
2.1 General demand.....	15
2.2 Heating and retrofitting	22
2.3 Transport	44
2.4 Cooking demand	55
3 Renewable energy technologies assessment	58
3.1 Solar energy	58
3.2 Wind	67
3.3 Wave.....	74
3.4 Offshore wind.....	77
3.5 Tidal.....	77
3.6 Storage	77
3.7 RE regulations	79
3.8 Renewable energy technologies economic analysis.....	80
4 System integration	81
4.1 Current status	82
4.2 Modelling	85
4.3 Definition of scenarios	89
4.4 Results.....	91
4.5 Scenario comparison.....	99
4.6 Conclusion.....	104
5 References	105
6 Appendices	114
6.1 Heating and retrofitting assessment.....	114
6.2 Renewable energy technologies assessment.....	117
6.3 Renewable energy technologies economic analysis.....	144

List of Figures

Figure 1.1. The Aran Islands, located in Galway Bay on Ireland's west coast	11
Figure 1.2. The Aran Islands consist of three main islands	12
Figure 2.1. Aran Islands electricity consumption forecast methodology diagram	15
Figure 2.2. Load profile of Aran Islands, 2023 (raw data, 30 min interval)	16
Figure 2.3. Load duration curve of raw data	16
Figure 2.4. Composite load profile of three islands, 2023 (raw data, 30 min interval).....	17
Figure 2.5. A family of 5 household's electricity consumption of 18 months	18
Figure 2.6. Electricity consumption data (2023) projected by population record	19
Figure 2.7. The last 80 years of population data	20
Figure 2.8. Trend of residential electricity consumption per capita, Ireland	20
Figure 2.9. Composite hourly load profile 2030, Aran Islands	21
Figure 2.10. Weekday load demand	21
Figure 2.11. Weekend load demand.....	22
Figure 2.12. BER rating chart.....	26
Figure 2.13. Carbon dioxide emissions by fuel type (Government of Ireland, 2023)	26
Figure 2.14. Interview with an island inhabitant	30
Figure 2.15. Thermal assessment promotion.....	30
Figure 2.16. Cold spots around: A. insulated window and B. non-insulated window.....	32
Figure 2.17. Comparison between: A. double-glazed window and B. triple-glazed window	33
Figure 2.18. Building typology distribution and heatmaps on Inishmore 006 electoral area	34
Figure 2.19. Scenario 2: 50% heat pumps annual load profile	38
Figure 2.20. Scenario 3: 100% heat pumps annual load profile	38
Figure 2.21. Type 1- detached house, stone walls, pre 1900 -2 storey.....	40
Figure 2.22. Scenario 2 cashflow	42
Figure 2.23. Scenario 3 cashflow	42
Figure 2.24. Charging for Mercedes-Benz eSprinter	47
Figure 2.25. Charging for LDV EV80	47
Figure 2.26. Daily load curve of electric cars during the rest of the year (a) and summer (b)	49
Figure 2.27. Annual load profile for 100% private electric vehicle scenario	49
Figure 2.28. Typical daily load curve for minibuses for different seasons	50
Figure 2.29. Annual load profile for 100% public electric minibuses scenario	50
Figure 2.30. Factors influencing EV purchase in Ireland	54
Figure 2.31. Cooking devices in the interviewed households (n=15)	56
Figure 2.32. Estimated occupancy at the permanently occupied homes and holiday homes ...	57
Figure 2.33. Monthly cooking demand profile for electricity-based cooking	57
Figure 3.1. Solar PV area suitability mapping process	58
Figure 3.2. Final suitability map for Aran Islands.....	62
Figure 3.3. Potential sites for solar parks in the Aran Islands	64
Figure 3.4. Annual energy production in the Aran islands	64
Figure 3.5. Time series of hourly data for south-facing system	66
Figure 3.6. Methodology for wind resource assessment.....	67
Figure 3.7. Study area map	68
Figure 3.8. Map of suitable areas for wind turbines	71
Figure 3.9. AEP for point absorber type WEC	76
Figure 3.10. Wave energy annual hourly generation	76
Figure 4.1. Snapshot of the transmission and distribution network.....	82

Figure 4.2. Probability of outages	83
Figure 4.3. Grid emission factor forecast.....	83
Figure 4.4. Energy price trends in consumer level	84
Figure 4.5. Simplified load profile calculation process	86
Figure 4.6. Excel model flow diagram	88
Figure 4.7. Wool demand balance	92
Figure 4.8. Wool generation balance	92
Figure 4.9. Wool scenario emissions	92
Figure 4.10. Wool emissions vs. DN	92
Figure 4.11. Wool capex per technologies (MEUR)	93
Figure 4.12. Wool system savings (MEUR)	93
Figure 4.13. Wool system net savings	93
Figure 4.14. Sand demand balance	94
Figure 4.15. Sand generation balance	94
Figure 4.16. Sand generation mix	94
Figure 4.17. Sand scenario emissions	95
Figure 4.18. Sand emissions vs. DN	95
Figure 4.19. Sand total CAPEX (MEUR)	95
Figure 4.20. Sand CAPEX per technologies (MEUR)	96
Figure 4.21. Sand system savings (MEUR)	96
Figure 4.22. System net savings Sand	96
Figure 4.23. Stone demand balance.....	97
Figure 4.24. Stone generation balance	97
Figure 4.25. Stone generation mix.....	97
Figure 4.26. Stone scenario emissions	98
Figure 4.27. Stone emissions vs. DN	98
Figure 4.28. Stone total CAPEX (MEUR)	98
Figure 4.29. Stone CAPEX per technologies (MEUR).....	99
Figure 4.30. Stone system savings (MEUR)	99
Figure 4.31. Stone system net savings.....	99
Figure 4.32. Demand per sector comparison.....	100
Figure 4.33. Generation mix comparison.....	100
Figure 4.34. Demand and supply comparison	101
Figure 4.35. CAPEX comparison	101
Figure 4.36. NPC lifetime comparison.....	102
Figure 4.37. System savings comparison	102
Figure 4.38. Net savings comparison	103
Figure 4.39. Emission comparison	104
Figure 6.1. Online survey of home insulation results	114
Figure 6.2. Online survey of heating status results	115
Figure 6.3. Online survey of willingness for transition results	115
Figure 6.4. Online survey of housing details results	116
Figure 6.5. Seasonal load demand	117
Figure 6.6. Selection criteria used for site suitability of solar PV in Aran Islands	118
Figure 6.7. Reclassification of GHI dataset.....	118
Figure 6.8. Reclassification of slope dataset	119
Figure 6.9. Reclassification of aspect dataset	119
Figure 6.10. Landcover categories of the study area	120

Figure 6.11. Classification of landcover dataset	120
Figure 6.12. Reclassification of road networks dataset	121
Figure 6.13. Distance from buildings	121
Figure 6.14. Archaeological sites in Aran Islands	122
Figure 6.15. Special Area of Conservation and Special Protection Area dataset	122
Figure 6.16. Weighted overlay of factors layer	123
Figure 6.17. Final constraint layer	123
Figure 6.18. Building footprints in the Aran Islands	124
Figure 6.19. Solar power generation southwest-facing system	124
Figure 6.20. Solar power generation southeast-facing system.....	125
Figure 6.21. Solar power generation east and west facing system	125
Figure 6.22. Power density suitability map	126
Figure 6.23. Proximity to roads suitability map	127
Figure 6.24. Proximity to buildings suitability map	127
Figure 6.25. Landcover suitability map	128
Figure 6.26. Slope suitability map	128
Figure 6.27. Annual hourly wind speed graph at 80m.	129
Figure 6.28. Capacity factor of IEC classes	129
Figure 6.29. Energy yield result for suitable location at Inishmaan.....	130
Figure 6.30. Shadow flicker effect results at Inishmaan	131
Figure 6.31. Noise effect result at Inishmaan.....	132
Figure 6.32. Visibility evaluation result at Inishmaan	133
Figure 6.33. Energy yield result for suitable location at Inishmore	134
Figure 6.34. Shadow flicker effect results at Inishmore	135
Figure 6.35. Noise effect result at Inishmore	136
Figure 6.36. Visibility evaluation result at Inishmore	137
Figure 6.37. The annual mean wave power resource (kW/m metre of wave crest)	138
Figure 6.38. Annual accessibility based on CTV operating limits	138
Figure 6.39. Annual accessibility based on HLV operating limits	139
Figure 6.40. The water depth between 0 and 150	139
Figure 6.41. Folk 7 classification of Seabed character.	139
Figure 6.42. Excavatable areas	140
Figure 6.43. The busiest areas for general shipping.....	140
Figure 6.44. The busiest areas for fishing.....	140
Figure 6.45. Subsea cable connecting Aran Island to the mainland	141
Figure 6.46. Protected areas.....	141
Figure 6.47. Wind speed 100m hub height.....	143
Figure 6.48. Mean peak current velocity on spring tides (m/s).	144

List of Tables

Table 1.1. General assumptions	14
Table 2.1. House type in the Aran Islands	23
Table 2.2. Pre-retrofit U-values considered for each house type.....	24
Table 2.3. Retrofit measures considered for house type 1	25
Table 2.4. Regression correlation results	27
Table 2.5. Pre-retrofit and post-retrofit U-values and energy demands for each house type	30
Table 2.6. Energy savings and CO2 emissions reductions associated with retrofitting.....	31
Table 2.7. Retrofitting scenarios considered in this study.....	31
Table 2.8. Survey result compared to CSO statistics.....	33
Table 2.9. Total houses surveyed and their energy demand.....	34
Table 2.10. Housing stocks and energy consumption calculation result	35
Table 2.11. Validation of result	36
Table 2.12. Space heating final energy demand	36
Table 2.13. Hot water final energy demand.....	37
Table 2.14. Total final energy demand of space heating and hot water.....	37
Table 2.15. Emission from final energy consumption in residential heating.....	37
Table 2.16. Types of houses and associated costs per house.....	40
Table 2.17. Types of houses and associated costs per house.....	41
Table 2.18. Retrofitting cost of each scenario	41
Table 2.19. Energy Savings from each scenario	42
Table 2.20. Cost comparison: cost of energy saving per kWh	43
Table 2.21. Cost of energy saving: type 1	43
Table 2.22. Frequently observed vehicle models on Inishmore during the study	45
Table 2.23. EV Charger Types (AC)	46
Table 2.24. Comparison of electric van features.....	47
Table 2.25. Assumed parameters to calculate cost-benefit parameters	51
Table 2.26. Diesel covered by buses in different seasons.....	51
Table 2.27. Annual cost for charging an EV	52
Table 2.28. Estimated annual costs for owning a diesel vehicle or an EV at the island	53
Table 2.29. Distribution of daily cooking energy demand.....	57
Table 3.1. Reclassification values for datasets	59
Table 3.2. Reclassification values for landcover dataset.....	61
Table 3.3. Criteria weights	62
Table 3.4. Distribution of sites across the Aran Islands	63
Table 3.5. Number of buildings based on orientation from building footprints.....	65
Table 3.6. Technical specification of selected systems.....	65
Table 3.7. Total theoretical capacity of solar rooftop	66
Table 3.8. Suitability classification.....	70
Table 3.9. Weightage of factors for wind suitability map.....	71
Table 3.10. Area coverage for wind farm suitability map	72
Table 3.11. Yield at location 1 (Inishmaan)	72
Table 3.12. Yield at location 2 (Inishmore).....	73
Table 3.13. Wave site selection & identification criteria	74
Table 3.14. Wave energy converters comparison.....	77
Table 3.15. Technical specifications of rooftop solar storage system	78
Table 3.16. Technical specifications of central storage system	78

Table 3.17. Renewable energy generation supporting mechanism comparison	80
Table 4.1. Tariff overview of different suppliers	85
Table 4.2. Economic parameters of the system	86
Table 4.3. Roof top solar systems categories.....	86
Table 4.4. Surveys to community about relevance criteria of an energy system.....	89
Table 4.5. Summary of demand scenarios.....	90
Table 4.6. HOMER Pro optimization results of Wool scenario.....	91
Table 4.7. Wool scenario final supply parameters	91
Table 4.8. HOMER Pro optimization results of Sand scenario	93
Table 4.9. Sand final supply parameters.....	94
Table 4.10. HOMER Pro optimization results of Stone scenario	96
Table 4.11. Stone final supply parameters.....	97
Table 4.12. Scenarios summary	100
Table 6.1. Datasets used in the study.....	117
Table 6.2. Data sources	126
Table 6.3. IEC wind classes	126
Table 6.4. Technical data of Enercon E82 EP2 E4	129
Table 6.5. Comparison of WindPro results for suitable locations.....	138
Table 6.6. Key Regulatory limitations on rooftop wind turbines.....	142
Table 6.7. Key industrial or business setting limitations on rooftop wind turbines	142
Table 6.8 Offshore wind suitability limits	143
Table 6.9. Parameters for all RE technologies.....	144
Table 6.10. NPC for all RE technologies.....	145
Table 6.11. LCOE for all RE technologies.....	145

List of Abbreviations

3D - Three Dimensional	IEC - International Electrotechnical Commission
AC - Alternating Current	ISO - International Organization for Standardization
AEP - Annual Energy Production	LCOE - Levelized Cost of Electricity
AIS - Automatic Identification System	LDC - Load Duration Curve
BAU - Business-as-usual	LPG - Liquefied Petroleum Gas
BER - Building Energy Rating	MERRA - Modern-Era Retrospective Analysis for Research and Applications
BEV - Battery Electric Vehicle	MEUR - Million Euro
CAPEX - Capital Expenditure	MPPT - Maximum Power Point Tracking
CEG - Clean Export Guarantee	MSS - Microgeneration Support Scheme
CEGS - Community Energy Grant Scheme	NHA - Natural Heritage Area
CFOAT - Aran Islands Energy Cooperative	NPC - Net Present Cost
CO ₂ - Carbon dioxide	NPV - Net Present Value
CPI - Consumer Price Index	OPEX - Operating Expenditure
CRU - Commission for Regulation of Utilities	OSM - Open Street Map
CSO - Central Statistics Office	PPA - Power Purchase Agreement
CTV - Crew Transfer Vessel	PSO - Public Service Obligation
CWA - Coastal Wave Atlas	PV - Photovoltaic
DC - Direct Current	RE - Renewable Energy
DECC - Department of Environment, Climate and Communications	REFIT - Renewable Energy Feed-in-tariff
DEM - Data Elevation Model	RESS - Renewable Energy Support Scheme
DN - Do-Nothing	SAC - Special Area of Conservation
EEM - Energy and Environmental Management	SAM - System Advisor Model
ESA - European Space Agency	SE - Southeast
EU - European Union	SEAI - Sustainable Energy Authority of Ireland
EUf - Europa-Universität Flensburg	SEM - Single Electricity Market
EUR - Euro	SHS - Solar Home System
EV - Electric Vehicle	SMR - Sites & Monuments Record
FIP - Feed-in-premium	SPA - Special Protection Area
GHG - Greenhouse Gas	SRESS - Small-scale Renewable Energy Support Scheme
GHI - Global Horizontal Irradiation	SW - Southwest
GIS - Geographic Information System	TBI - To be Implemented
HBS - Home Battery Storage	TFC - Total Final Consumption
HDH - Heating Degree Hours	VAT - Value Added Tax
HLV - Heavy Lift Vessel	VRT - Vehicle Registration Tax
HOMER - Hybrid Optimization of Multiple Energy Resources	WEC - Wave Energy Converter
HP - Heat Pump	WTG - Wind Turbine Generator
HTC - Heat transfer Coefficients	ZVI - Zones of Visual Influence
IC - International Class	
ICE - Internal Combustion Engine	

Executive Summary

The Aran Islands are actively pursuing a transition toward a more sustainable energy system, recognizing both the environmental and economic benefits of reducing dependence on fossil fuels. Despite being connected to the mainland grid, a significant portion of the islands' energy consumption, particularly in heating, cooking, and transportation, remains reliant on imported fossil fuels. This study explores potential pathways for the islands to achieve a more self-sufficient and low-carbon energy system while ensuring feasibility and community support.

A multidisciplinary approach was taken to assess the current energy landscape and identify viable transition strategies. The research involved community engagement through surveys and interviews, allowing insights into local energy consumption patterns and challenges. Additionally, a technical analysis was conducted to evaluate the potential for renewable energy generation, including solar, wind, and wave power. Energy system modelling was used to project future scenarios, integrating renewable energy technologies, demand-side efficiency measures, and sector electrification.

Four transition scenarios were developed to compare different pathways toward sustainability. The **Do-Nothing (DN)** scenario assumes no major changes, meaning continued reliance on fossil fuels and increasing emissions over time. The **Wool** scenario represents an incremental shift, with an increase in renewable energy integration while maintaining a strong dependence on the national grid. The **Sand** scenario expands electrification efforts, particularly in heating, cooking, and mobility, requiring a larger share of local renewable energy generation. The **Stone** scenario is the most ambitious, aiming for near-complete energy independence through full electrification and maximum utilization of available renewable resources.

The results indicate that achieving a net-zero energy system on the Aran Islands is technically feasible. However, the cost and infrastructure requirements vary significantly between scenarios. Energy efficiency measures, particularly in building retrofitting and demand-side management, emerged as critical factors in minimizing costs and reducing the fossil fuel dependency. Without such measures, achieving full decarbonization would not be possible without extensive investments in renewable capacity and storage solutions.

Ultimately, this study provides a roadmap for the Aran Islands to make informed decisions regarding their energy transition. The findings highlight the importance of a balanced approach that combines renewable energy expansion, efficiency improvements, and strong community engagement. Moving forward, policy support, financial incentives, and continued stakeholder engagement will be essential in ensuring a successful and sustainable transition to a low-carbon future.

1 Introduction

The International Class (IC) is a compulsory module of the Master of Engineering in Energy and Environmental Management (EEM) programme of Europa-Universität Flensburg (EUF), Germany. The IC module allows students to work as a team on an interdisciplinary, real-world, applied energy challenge within a time frame. IC makes it possible for students and teaching faculty to utilize a problem-solving approach in exploring and solving energy issues encountered by society. A key part of this module is to engage with the community and the local stakeholders in devising and implementing efficient solutions to the problems analysed.

The IC2025 took place in the Aran Islands, a group of three islands located approximately 10-13 km from the coast of County Galway, Ireland; Inis Mór (Inishmore), Inis Meáin (Inishmaan), and Inis Oírr (Inisheer) at the mouth of Galway Bay, off the west coast of Ireland as shown in Figure 1.1. The islands are famous for their beautiful landscapes and cultural heritage, and with the Irish-speaking traditional communities, the islands offer a taste of Ireland's history.



Figure 1.1. The Aran Islands, located in Galway Bay on Ireland's west coast

The islands are shown in Figure 1.2; they are the home to approximately 1,347 inhabitants, with tourism being the foundation of the local economy. It is these towering cliffs, old stone forts, and deeply rooted Gaelic culture that bring tourists to the Aran Islands. The region is also classified as a Special Protected Area due to the presence of a distinct biodiversity and ecological significance (Clean Energy for EU Islands, 2019).



Figure 1.2. The Aran Islands consist of three main islands

The IC2025 study is a collaboration between the EEM department of Europa-Universität Flensburg and the Aran Islands Energy Cooperative (CFOAT), focusing on CFOAT Goal 4: enhancing the comfort, energy efficiency, and sustainability of homes and transport. A key aspect of this study is the exchange of knowledge between students and researchers from the University of Galway, Ireland, and IC2025 students from Europa-Universität Flensburg. This collaboration had been further strengthened through an excursion, facilitating valuable discussions and research exchange, with special thanks to our partner, Ms. Dayanne Peretti from the University of Galway.

This study examines the electricity and heat necessities of the islands, assesses inefficiencies, and identifies possibilities for efficiency improvement through retrofitting, procedures involving community engagement activities comprised of surveys, community interviews, and visits with regular coordination with the energy cooperative (CFOAT). It also quantifies energy use in cooking and transportation using electric vehicles (EVs). It assesses the feasibility of renewable energy resources that can meet the demand for energy in the Aran Islands and conducts an economic analysis of solar, wind, and wave energy technology.

Based on these findings, an integrated sustainable energy system has been developed to meet the energy requirements of the Aran Islands, reducing dependence on the national grid, and becoming energy self-sufficient.

1.1 Objectives

CFOAT Goal 4 has been the main objective of the study, which has been further broken down into sub-objectives.

1. Achieving energy sustainability and meeting demand with renewable energy (RE) resources for the Aran Islands.
2. Increasing the comfort, energy efficiency, and sustainability of buildings in the Aran Islands, focusing on stakeholder engagement and house surveys.
3. Assess the feasibility of expanding electric vehicle (EV) adoption on the Aran Islands, focusing on infrastructure needs, stakeholder engagement, and the environmental and economic impact.
4. Development of an Integrated sustainable system that can meet the energy demand of the Aran Islands.

1.2 Community engagement

Community engagement is a critical factor in understanding public perception and acceptance of the energy transition. Meaningful change is not possible without community support, as the transition begins at the household level.

In our study, we prioritized community involvement with the support of our stakeholder, CFOAT. Prior to our arrival, CFOAT informed residents about our visit, providing an introduction about our team and the duration of our stay on the island.

Upon arrival, we actively engaged with the local community by introducing ourselves in various public spaces, such as bars, shops, and souvenir stores. We invited residents to participate in interviews, sharing their experiences of daily life on the island. Our discussions covered the four key aspects of our study: renewable energy, heating and retrofitting, electric vehicles, and the integrated grid system. As an example, we inquired about their willingness to adopt solar rooftop systems, their current heating solutions, past experiences with electric vehicles, and the challenges they faced regarding the island's electricity grid.

We were pleased to receive responses on all topics and engage in insightful discussions. The community expressed a wide range of perspectives, reflecting diverse lifestyles and housing conditions. Among the residents, we met individuals who owned electric vehicles, had installed solar panels, and lived in well-retrofitted homes with a high level of insulation. Many also shared their experiences during power outages caused by storms. It was encouraging to see that the community was well-informed about energy-related issues and demonstrated a willingness to engage in discussions on the topic.

Additionally, to broaden our outreach, we organized two community events during our stay on the Aran Islands, further strengthening dialogue and participation in the energy transition process. Later in each aspect of our study, details of the community engagement findings are shared.

1.3 General assumptions

The following general assumptions have been used throughout this document.

Table 1.1. General assumptions

Parameter	Value	Units	Source
Current Population	1347	People	(Central Statistics Office, 2022)
Population projected	1400	People	Section 2.1.1.3.1 Population growth
Social Discount Rate	4%	-	(DOPE, 2025)
Inflation rate	2%	-	(Macrotrends, 2025)
Lifetime of a wind project	20	yr	Assumption
Lifetime of a PV project	20	yr	Assumption
Lifetime of a Wave project	20	yr	(Pennock et al., 2022)
Qty. of Occupied Houses in the 3 islands	502	Houses	(CSO, 2022)
Qty of private cars on the 3 islands	359	Car	(J. Rivas et al., 2018)
Qty. of electric vehicles in the 3 islands (existing)	25	eCar	CFOAT estimate
Qty. of buses in the 3 islands	26	Bus	(J. Rivas et al., 2018)
Qty. of electric buses in the 3 islands (existing)	0	eBus	CFOAT estimate
Qty. of houses with SHS (existing)	92	Houses	Estimated based on installed capacity
Actual SHS capacity installed	370	kWp	CFOAT estimate
Actual battery capacity installed	256	kWh	CFOAT estimate
Qty. of houses with HP (existing)	50	Houses	(Data Cellar, 2025)
Feed in Tariff (average 7 suppliers)	0.19	EUR/kWh	(Bord Gáis, 2025)
Price per kWh - average	0.297	EUR/kWh	(SEAI, 2025)
Price per kWh - nighttime	0.149	EUR/kWh	(SEAI, 2025)
Cost of diesel (transport)	1.9	EUR/l	Fuel pump at the Aran islands
Cost of coal	0.95	EUR/kg	SPAR Kilronan
Cost of heating oil	1.27	EUR/l	Co-op
Cost of Kerosene	1.4	EUR/l	Fuel pump at the Aran islands
Cost of Wood	2.50	EUR/kg	SPAR Kilronan
Cost of LPG	0.23	EUR/kWh	SPAR Kilronan
Diesel emissions factor	241	gCO ₂ /kWh	(SEAI, 2024)
Coal emissions factor	340	gCO ₂ /kWh	(SEAI, 2024)
Heating oil emissions factor	273.6	gCO ₂ /kWh	(SEAI, 2024)
Kerosene emissions factor	257	gCO ₂ /kWh	(SEAI, 2024)
LPG emissions factor	229.3	gCO ₂ /kWh	(SEAI, 2024)
Grid Emission Factor Consumption 2023	254.8	gCO ₂ /kWh	(SEAI, 2024)
Grid Emission Factor Consumption 2030	168.52	gCO ₂ /kWh	(SEAI, 2024)
Grid Emission Factor Generation 2023	229.9	gCO ₂ /kWh	(SEAI, 2024)

2 Demand assessment

2.1 General demand

To assess the renewable energy possibilities for the Aran Islands, the first step is to assess the current electricity demand of the islands and project it to 2030.

2.1.1 Methodology

As depicted in Figure 2.1, the methodology has been applied to estimate the Aran Islands' electricity consumption in 2030. Firstly, separate raw data from Inishmore, Inishmaan and Inisheer has been assessed separately. The overall shape of the load provided the load profile and the load duration curve plotting. Because the integrated system of the whole 3 islands is this study's scope, only the summation of the data has been further analysed. Secondly, data has been benchmarked with different other studies to represent the reality. Furthermore, the data has been prepared to feed the forecasting to 2030. Lastly, to project 2030 only electricity demand, heating and EV current demands has been dropped to not to double account. Then the future influencing factors has been estimated.

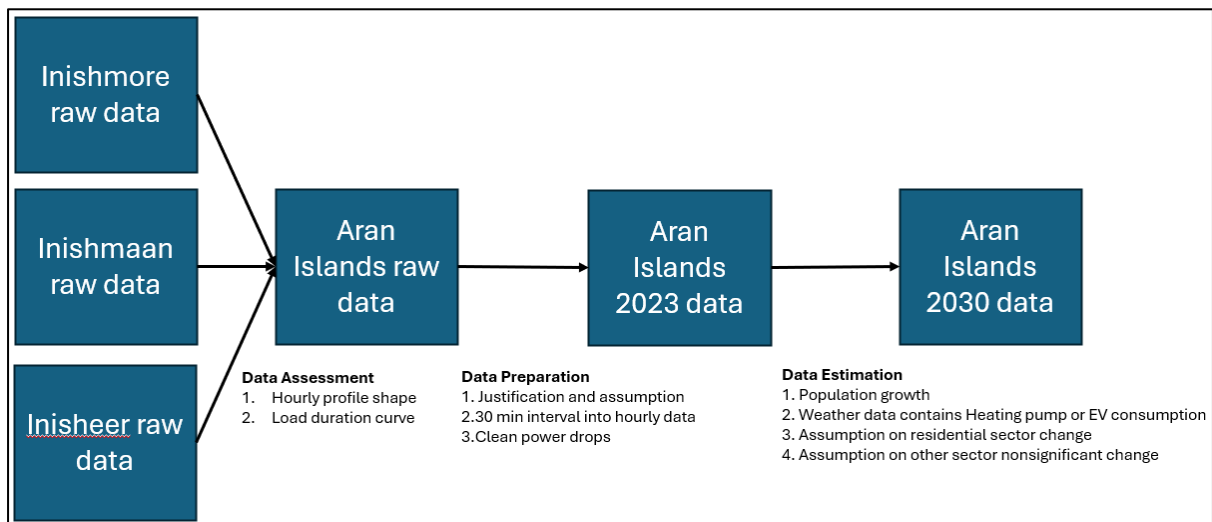


Figure 2.1. Aran Islands electricity consumption forecast methodology diagram

2.1.1.1 Data assessment

To understand the performance and errors of the data in detail, the following analysis has done.

2.1.1.1.1 Hourly profile shape

Aran Islands energy co-operative provided individual Inishmore, Inishmaan and Inisheer 30 min interval time series of electricity consumption of 2023. The data has been illustrated below. While the individual raw data provides a reasonable load ratio between the 3 islands in comparison with residents, the data had been recorded in several hours as constant, rectangular-shaped pattern occurred throughout the series, creating doubts on data accuracy.

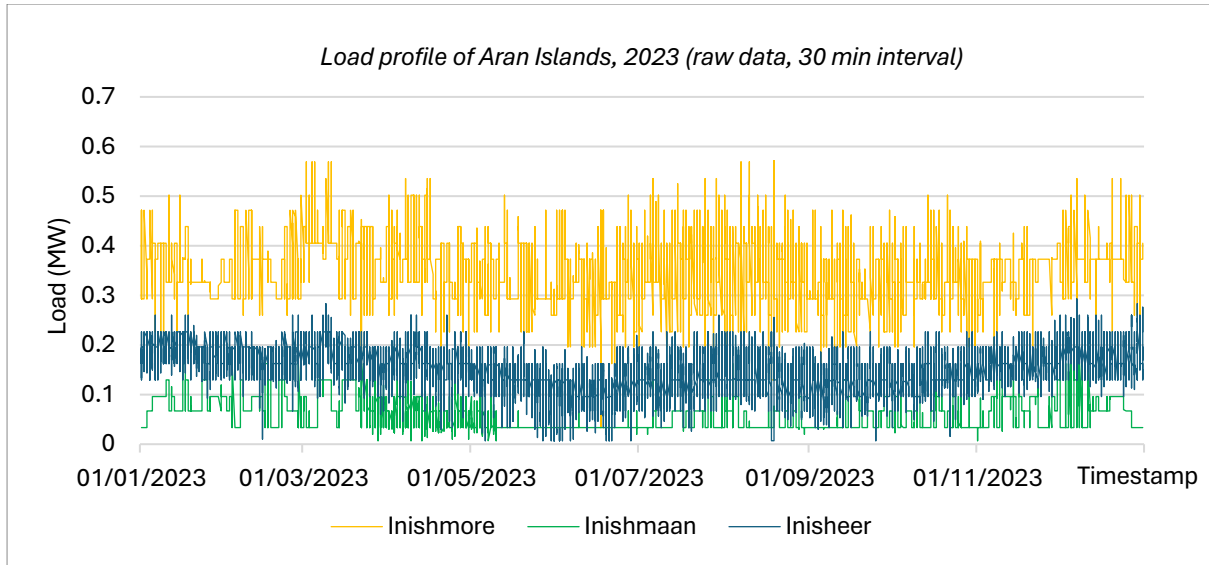


Figure 2.2. Load profile of Aran Islands, 2023 (raw data, 30 min interval)

Data source: (Aran Islands energy co-operative, 2024)

2.1.1.1.2 Load duration curve (LDC)

Further, all islands' data were plotted from highest to lowest order for further inspection. The Aran Islands 30 min time series was represented through combining the three islands' data. In Figure 2.3, load duration curve plot illustrates the distribution of power occurrence over certain time clearly. The step like appearance in these 3 islands suggests that these data were artificially developed, rather than recorded. In addition, Inishmaan's nearly 40% occurred load has been recorded as null. However, the combination of the islands has smoother appearance and balanced distribution. Even though data origin is doubtful, this presence and load profile creates confidence to consider these data as realistic recordings of the Aran Islands and to start with further proceedings with justification. Also, Aran Islands load duration curve is capable of providing peak, intermediate, and base loads.

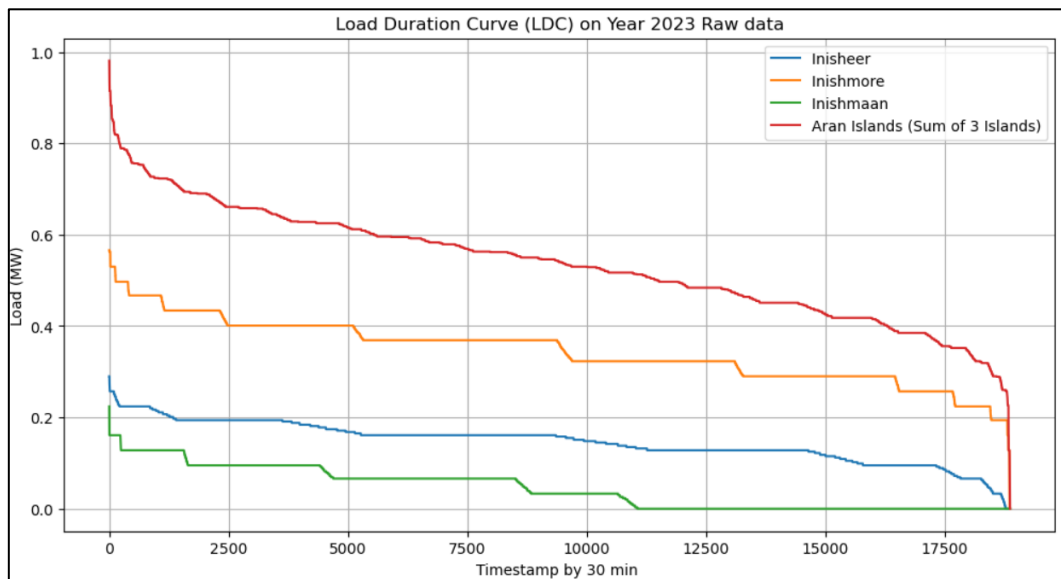


Figure 2.3. Load duration curve of raw data

Data source: (Aran Islands energy co-operative, 2024)

2.1.1.2 Data preparation

If the raw data for individual islands were considered as actual recordings, despite containing errors that were demonstrated in LDC and Load profile shapes, a slight modification could be made by replacing the null with low numbers that is common occurrence (Inishmaan and Inisheer 0.033 MW/30min and Inishmore 0.128 MW/30min); by this method, the total annual electricity demand would increase by 2.6%. But, to maintain data transparency and avoid artificial manipulation, this approach was not further pursued.

Furthermore, the Aran Islands' 30 min data have transformed into hourly data by averaging two records in 30 min of one hour. The representation of the hourly load profile of 2023 of Aran islands is shown in the following Figure 2.4. The sudden drops might be indicating the power cuts on 1st of April, 17th of June, 19th of August and 13th of September in 2023. To use these data to forecast the 2030 data, these drops were further cleaned by following the pattern of the previous week's same day.

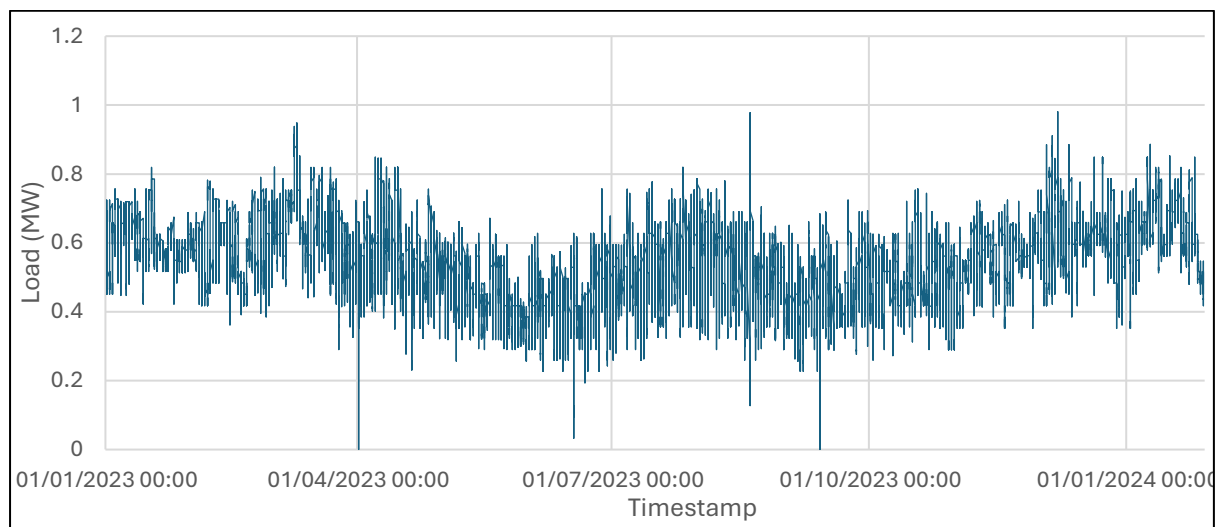


Figure 2.4. Composite load profile of three islands, 2023 (raw data, 30 min interval)

Data source: (Aran Islands energy co-operative, 2024)

2.1.1.2.1 Data justification

In 2014, Aran Islands tried to create a “clear picture” on energy consumption through the SMILEGOV project. This energy audit study was published on 2015 October. According to the estimation based on 2013, the population was 1200 (in addition, the author considers visitors, which is irrelevant in this case, because the data being justified is accounting for total electricity consumption per annum). The report stated that imported electricity is 2500 MWh and electricity by local Renewable Energy is 1750 MWh, targeting to generate in 2022 (Christian Pleijel, 2015). This “Local RE” is referring to 3 wind turbines of Vestas V27 modelled 225 kW installed capacity parks, which stopped working in 2011 (Clean Energy for EU Islands, 2019) and was dismantled in 2013 spring (NEOCyce GmbH & Co. KG, 2023). During that time, there were no significant other renewable technologies that were introduced according to reviewed literature. Thus, these wind turbines were generating 1750MWh, which is convincing as considering the open-source web estimator (based on global MERRA-2 satellite 2019 data) called “Renewable Ninja”(Renewables ninja, 2019) exact location and exact wind turbine estimation suggesting 2448 MWh electricity generation from these 3 turbines. This calculation is done only to justify the energy audit estimation of 1750MWh generation statement is at acceptable to estimate as a supply, else the estimation had not been considering different factors such as year specified wind speed, detailed orography turbine production degradation and other detailed influences.

Which suggests that total electricity consumption of Aran islands was 4250 MWh in 2013. Also, Clean Energy Transition Agenda document (Clean Energy for EU Islands, 2019) highlighted that these turbines were supplying 40% of electricity demand in 2011. In 2011, according to national statistics, the population was 1251 in Aran islands (Central Statistics Office, 2022). This provides an insight that electricity demand on the Islands was about 4375 MWh.

This conclusion would contest the estimation of Energy Master Plan 2018, total final consumption (electricity) of 2257 MWh from Inishmore and Inishmaan in base year of 2017 (J. Rivas et al., 2018). The time series data has been provided from ESB networks, similar with this report, 30 min interval time series. According to the national statistics, Inishmore had 762, Inishmaan had 183 and Inisheer had 281 residents in 2016 (Central Statistics Office, 2022). The plan has considered 2 of the islands and when scaled up to include the entire Aran Islands based on population, the estimated total electricity consumption would be approximately 2,928 MWh. This demand also has been further referenced several times, for example, Suna et al. said 2915 MWh electricity demand in 2017 and projected 2934MWh in 2030 (Suna et al., 2020b).

To answer Aran Islands' electricity demand range more clearly, similar islands have been compared. The Inishbofin island, located near to the Aran islands, has 183 residents as same as Inishmaan and finished energy planning in 2022 (Inishbofin Development Company DLC, 2022). The total electricity consumption projected one-month net metering into annually, around 753MWh. If Inishbofin demand was projected into Aran islands population, it would result in 5542 MWh.

Third way to testify the data validation was on-site visit. The family of 5 consumed approximately 7.8 MWh electricity in 12 months Inishmore in Figure 2.5. While single household consumption is not sufficient to estimate Aran islands general consumption, it is a validation that a consumption of the residential sector consumption per person is 1.5 MWh annually. While the Energy Master plan estimated total consumption of residential sector was 537MWh (Aran Islands energy co-operative, 2018). If, in 2017, total residents where 1230 people then residential sector consumption per person had estimated around 0.4 MWh annually which results in a high gap between reality and estimation.



Figure 2.5. A family of 5 household's electricity consumption of 18 months

Thus, by having several sources, the raw data has been projected back from 2023 to 2011 by populations to compare and justify the original data as shown in Figure 2.6.

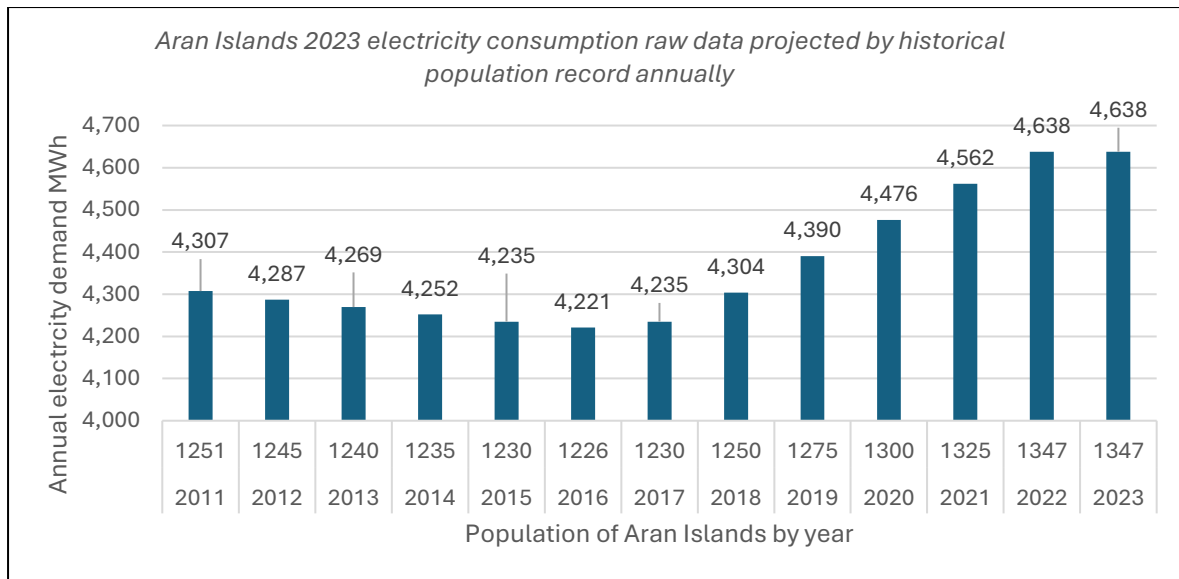


Figure 2.6. Electricity consumption data (2023) projected by population record

Population data source: Year 2011, 2016 and 2022 (Central Statistics Office, 2022b), other years has been estimated using a polyline trend except 2023 (Polyline trend did not consider Covid impact on islands)

Consumption data source: (Aran Islands energy co-operative, 2024)

To conclude, the Aran Islands annual electricity consumption should be higher than 4 GWh and by considering that partial historical demand has been already supplied by 370 kW installed solar PVs (Aran Islands Energy Co-op, 2025) the raw data of total 4637.9 MWh electricity consumption of 2023 has proven to be valid for further energy system modelling.

2.1.1.3 Data estimation

As previously mentioned, to only forecast the electricity general consumption, heating and EV shares has been dropped to duplicate the accounting, which share affects all estimation the dedicated factor has been weighted as 1.

Because the changes in the population would impact overall demand, changes and estimated population growth has been weighted as 1.

Additionally, the electricity consumption residential change has been considered as 30% change based on the rounding estimation in 2017 households' consumption was 29% in Inishmore (Aran Islands energy co-operative, 2018). This factor has been assigned a weight of 0.3.

According to SEAI survey on 2017 data summarized by energy master plan (J. Rivas et al., 2018; SEAI, 2017), in Inishmore sector shares were:

- Commercial: 20.9% (primarily hotels and the Spar shop etc.)
- Industrial: 1.8%
- Public Buildings: 12.1% (community buildings, office service buildings, 3 schools etc.)
- Utilities: 35.7% (recycling plant, water treatment plants, public lighting) etc.
- Other: 0.5%

Since no significant changes have been observed in these sectors, they have been excluded from the forecast to simplify the estimation.

2.1.1.3.1 Population growth

The total of Aran Islands population is dramatically decreasing throughout the years from 3500 people in 1841 to 1347 in 2022 (Central Statistics Office, 2022a). Thus, to accurately estimate

the 2030 population projection last 80 years of data considered. Population in recent years has been growing as well as positive expectation of locals (James Wilson, 2023) and Suna D et al.'s assessment expected population of 1238 in 2030 (Suna et al., 2020) which has been exceeded leads to consider interpolated polyline projection as shown in Figure 2.7. Thus, the population in 2030 is considered in total of 1400 inhabitants.

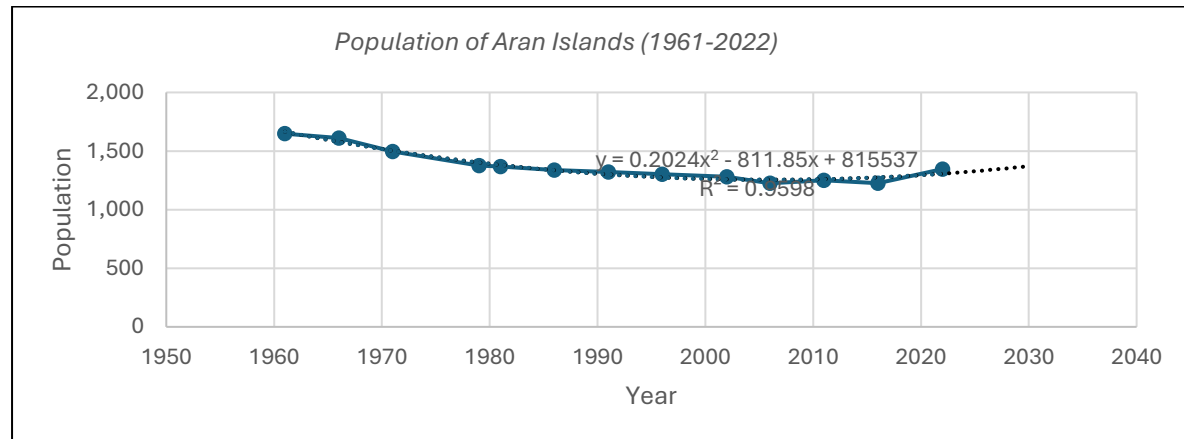


Figure 2.7. The last 80 years of population data

Data source: (Central Statistics Office, 2022a)

2.1.1.3.2 General demand excluding consumption of EV and heat pump

By referencing the previous study of Suna et al., in 2017, 97% was electricity utility consumption, 2.3% was heat pumps and 0.3% was EV consumption on the Aran Islands. Therefore, only to estimate electricity consumption from utilities heating pump and EV has been separated from the data by only considering 0.97 as an influencing factor on the forecast.

2.1.1.3.3 Residential electricity consumption

From 2004 to 2023 Residential total consumption of the Ireland data from SEAI (Sustainable Energy Authority of Ireland, 2024b) has been divided by total residents of the country (World Bank, 2024) to roughly estimate the historical trend of the energy efficient utilities increase and growth of electricity residential consumption per capita. Next, by drawing a linear trendline the behaviour of single resident energy consumption of 2030 has been determined. The consumer behavioural consumption would decrease according to the trendline by roughly 3%.

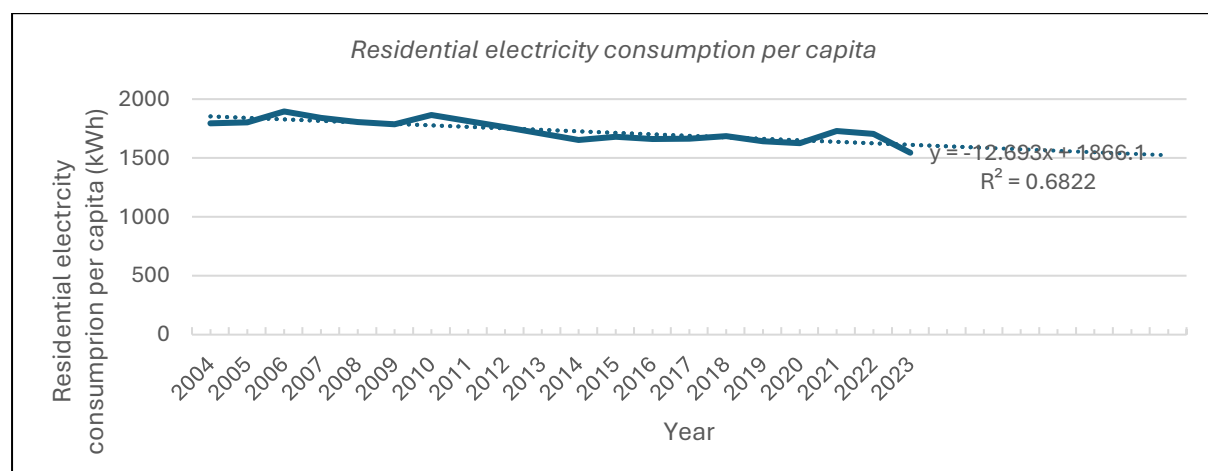


Figure 2.8. Trend of residential electricity consumption per capita, Ireland

Data source: A correlation based on residential electricity consumption and Population of Ireland (Sustainable Energy Authority of Ireland, 2024c; World Bank, 2024)

2.1.2 Resulting electricity demand

In Business-as-usual scenario expected total demand is 4538 GWh. The following graph describes the annual consumption of the Aran Islands in 2030 based on only electricity perspective.

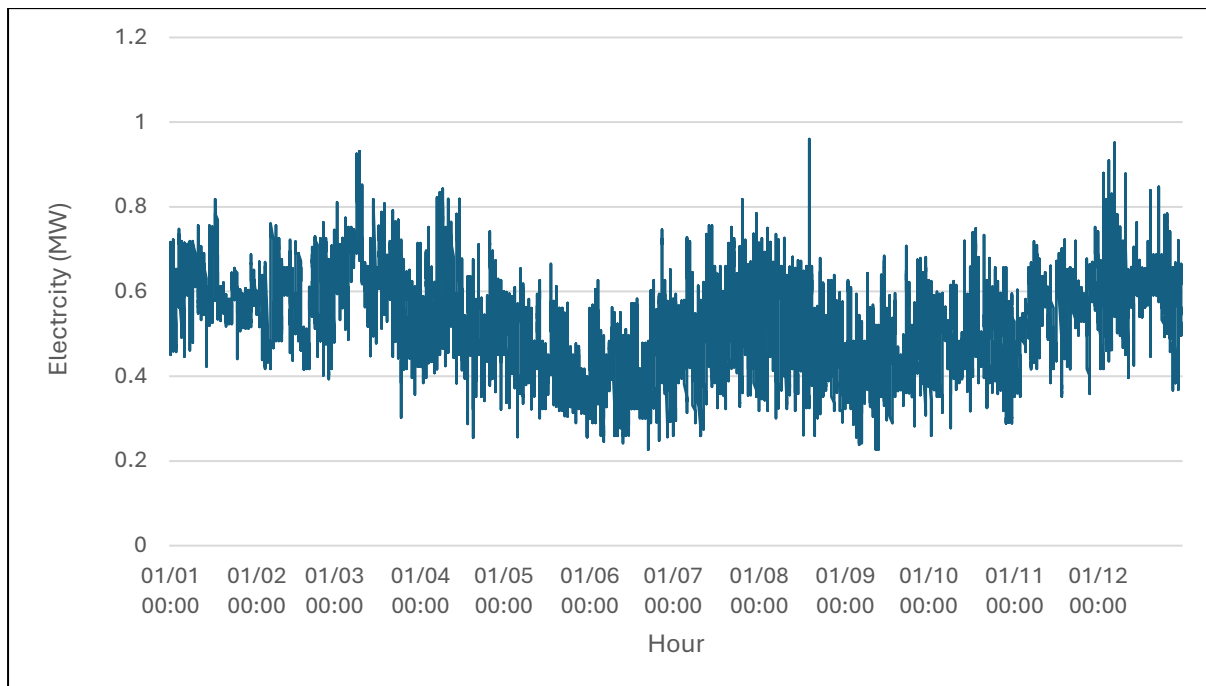


Figure 2.9. Composite hourly load profile 2030, Aran Islands

A typical weekend and weekdays pattern has been described in the following figure. Consumers started to be active around 8 AM and peak demand occurs around 7 PM.

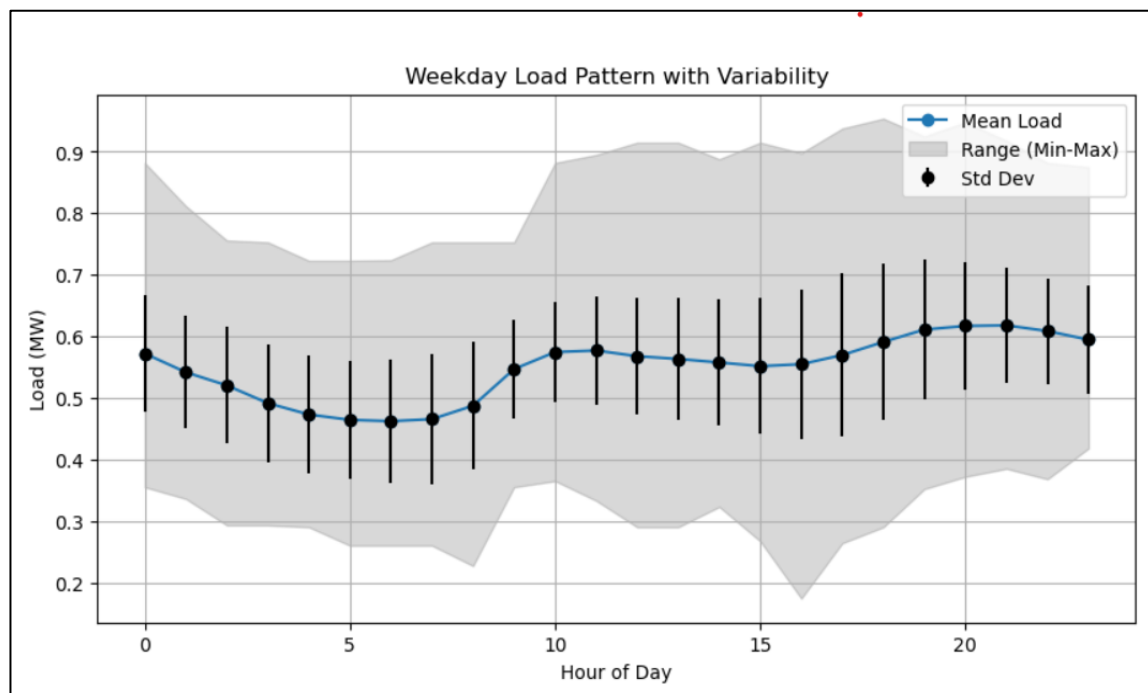


Figure 2.10. Weekday load demand

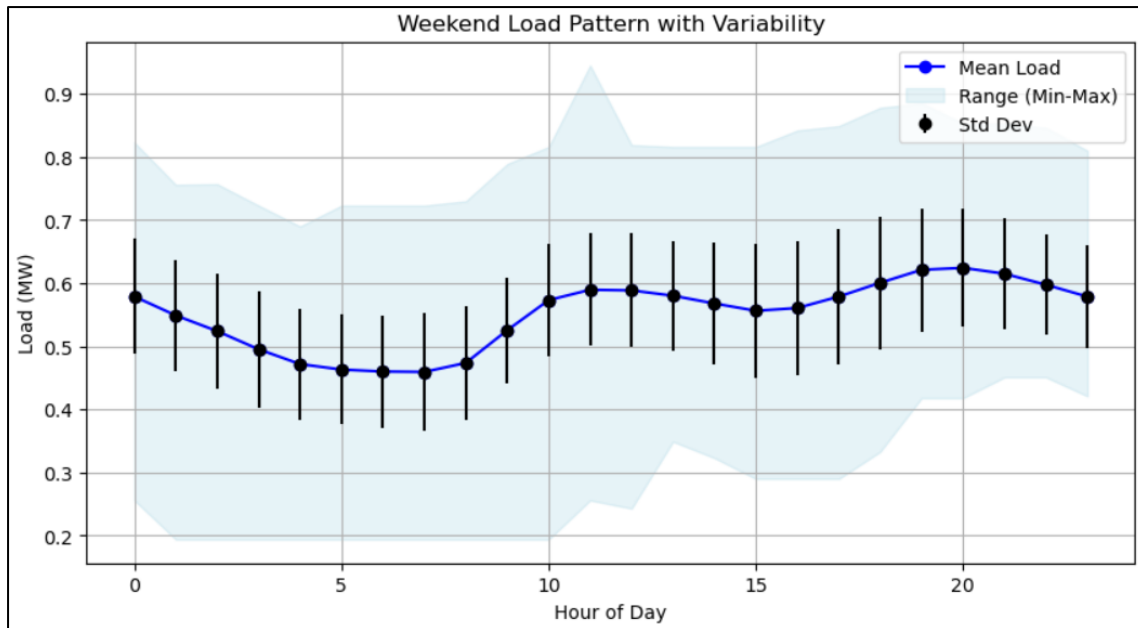


Figure 2.11. Weekend load demand

Similarly, by categorizing the seasons as Winter (December, January and February), Spring (March, April, and May), Summer (June, July and August) and Autumn (September, October, and November) it is feasible that seasons have distinct characteristics throughout the week. Summer is showing high fluctuations in the night and day while in the winter the energy consumption is relatively high. This behaviour can be described in relation to the heating demand because electricity consumption includes electric heaters. Also, this behaviour can be related to the inside and outdoor activities of consumers.

2.2 Heating and retrofitting

Heating is considered an important aspect that every home is having as it is a must for indoor comfort. When studying the heating aspect regarding energy consumption and how to make it sustainable, it is needed to also focus on the retrofitting of houses from the insulation factor perspective. This takes us through the details of sustainable heating systems and retrofitting of buildings on the Aran Islands. Focusing on their role in consuming less energy and having a green environmental impact. While Heating systems have developed a lot regarding energy efficiency over the decades, we find that they still account for a big share of household energy use, that is why it is important to put effort in finding the optimum heat solutions that operate efficiently without polluting the environment. So, our perspective is to focus on studying and planning the transition to efficient and renewable heating systems in the Aran islands. There is a high potential for transition to renewable heating since Inishmore has had an average thermal fuel TFC import of 6,500 MWh per annum. The most predominant imports are coal, kerosene and gasoil. Kerosene is the main import (average of 32%) followed by Gasoil (26%) and Coal (25%).

The primary goal of this study is to support the Aran Islands in improving the comfort, energy efficiency, and sustainability of residential buildings, aligning with the objectives of CFOAT and key stakeholders. To achieve this, the study evaluates the current heating systems on the islands and analyzes their energy demand in respect to energy efficiency measures such as retrofitting. It also engages with the local community and stakeholders to understand their perspectives and challenges on retrofitting and applying green technology heating solutions in the Island. Additionally, the research assesses the effectiveness and long-term cost benefits of retrofitting strategies for the community. Finally, it explores potential scenarios for transitioning to a fully heat pump-based heating system, contributing to long-term sustainability and energy efficiency.

2.2.1 Methodology

2.2.1.1 Heat demand assessment

This study uses spatial analysis to estimate heating demand across the Aran Islands by combining building footprint data from OpenStreetMap (OSM) with direct observations from a local survey. The survey first categorizes houses on the islands to identify common building types. It then enhances the OSM data by adding details about building characteristics, such as the number of floors and house type, which are not included in the original dataset. Energy demand is calculated for each house type based on the thermal properties of assumed building materials, structural characteristics, and local Heating Degree Hours (HDH). The results are first determined for the surveyed areas, accounting for differences in house sizes within each category. To assess the impact of energy efficiency improvements, the process is repeated using different U-values for retrofitted houses based on various scenarios. Finally, the average heating demand per house type is used to estimate the total heating demand for the entire island, with adjustments based on building construction data from the Central Statistics Office (CSO).

2.2.1.2 Typology of houses in the Aran Islands

The classification of buildings into representative categories represents the common types of houses found on the island. This categorization facilitates the estimation of heating demand for groups of similar buildings. Numerous research highlights the strong correlation between building form and operational energy demand, shows the importance of typology in energy modelling (Cody et al., 2018).

Table 2.1. House type in the Aran Islands

Data source: (CSO, 2022; Tabula, 2014)

Type	Estimated built year	Sample pictures	Description	House stocks in Aran Islands	Estimated average heat demand (kWh/year)
1	Pre 1900-1920		Detached, 2-storey	84	11,400
2	1920-1980		Detached or semi-detached, 1-storey	204	13,500
3	1981-1990		Detached, 1 storey	70	6,900
4	1990-2000		Detached, 2-storey	56	5,800
5	2001-2010		Detached, 1 or 2-storey	56	9,300
6	2011-Now		Detached, 1 or 2-storey	32	8,100

Since no sufficient data was available, the building types on Aran Island were identified through direct observation and local resident's validation. Around 300 houses in Inishmore were observed and classified based on the typology of Irish buildings from Tabula (2014). The houses were grouped into six types according to their architectural features and estimated construction periods, making the modelling process simplified. These classifications were determined by recognizing common architectural patterns and styles of the houses across Inishmore, offering insight into the island's housing development over time. The identified house types are presented in Table 2.1.

2.2.1.3 Assessing demand and the retrofitting process

2.2.1.4 Estimating heating demand for different house types

The assessment of retrofitting potentials started with an estimation of the current heat demand for different house types on the island. The process was done using a combination of existing building types, U-values, and HDH, acting as a baseline for determining appropriate retrofit measures.

The Tabula building typology for Irish dwellings (Tabula, 2014), was used as the primary resource for categorizing house types (see section 2.2.1.2), which enabled us to calculate heat transfer coefficients (HTC) and the annual heating demand for each house type before and after retrofitting.

2.2.1.5 Pre-retrofit quantitative analysis

With U-values derived from the Tabula brochure, pre-retrofit calculations were made to determine heat loss through the building envelope, and the SEAI BER database provided the surface area measurements for each house type. Calculations were made using Microsoft Excel and Table 2.2 provides a summary of the pre-retrofit U-values considered for this study.

Table 2.2. Pre-retrofit U-values considered for each house type

House Type	U-Value Walls (W/m ² K)	U-Value Roof (W/m ² K)	U-Value Floor (W/m ² K)	U-Value Window (W/m ² K)	U-Value Door (W/m ² K)
1	2.1	0.68	0.65	4.8	3
2	1.78	0.68	0.65	5.7	5.7
3	0.55	0.41	0.26	2.8	3
4	0.55	0.26	0.41	2.8	3
5	0.37	0.2	0.34	2	3
6	0.37	0.2	0.34	2	3

Whereas the above U-values were considered for the calculation, it is important to note that building standards on the island have evolved over the past decade. Our field observations revealed that, for example, many houses have upgraded to double or triple-glazed windows, indicating ongoing improvements in building energy efficiency on the Island.

2.2.1.5.1 Calculating heat transfer coefficient

The HTC which quantifies the overall heat loss rate (W/K) associated with each house type was calculated according to Equation 2.1 (Rawat et al., 2024; Yu et al., 2024).

$$HTC = \sum (U_i \times A_i) \quad \text{Equation 2.1}$$

Where; U_i is the U-value ($\frac{W}{m^2 \cdot ^\circ C}$), representing the rate of heat transfer through a building element, and A_i is the respective surface area in (m^2).

2.2.1.5.2 Annual heat demand estimation

From the HTC value estimate, the annual heating demand for each house type was calculated using Equation 2.2.

$$Q_{annual} = \frac{HTC}{1000} \times HDH \quad \text{Equation 2.2}$$

Where HDH is the Heating Degree Hours in $^{\circ}\text{C} \cdot \text{h}/\text{year}$, derived from local climate data, whereas 1000 represents a conversion factor from (Wh) to (kWh).

The HDH was computed according to Equation 2.3, with an assumed base temperature of 17°C .

The total HDH considered for this study is $49,046.4^{\circ}\text{C} \cdot \text{h}/\text{year}$.

$$HDH = \sum (T_{base} - T_{outdoor}) \quad \text{Equation 2.3}$$

2.2.1.6 Retrofitting process

Retrofitting involves upgrading an existing building to make it more energy efficient, enhance its heat retention capacity, and transition from the use of fossil-fuel-based heating systems to renewable energy heating solutions (Centre for Sustainable Energy, 2025). Retrofitting has been carried out on Aran Island, with over 50% of the houses reported to have undergone some form of retrofit (Clean Energy for EU Islands, 2019). In this study, we assessed the energy savings potential associated with retrofitting houses on the island using a bottom-up approach. With over 500 inhabited houses, the selected house types were analysed and used to estimate the overall retrofit impact by extrapolating the findings to the broader housing stock. Retrofitting measures such as enhanced insulation for walls, roofs, and floors (Papadopoulos, 2005), replacement of doors and windows with double or triple glazing, and/or upgrading heating systems to more efficient systems like heat pumps were considered and applied in steps as recommended by Tabula. Step 1 focused on roof insulation, Step 2 on wall insulation, Step 3 on windows, and door replacements, and Step 4 on heating system upgrades under the standard refurbishment. This approach was useful for recommending which house types could be considered first following the cost implication associated with the different cases. Table 2.3 gives an example of the retrofit measures considered for house type 1.

Table 2.3. Retrofit measures considered for house type 1

Step	Building Element	Pre-Retrofit Condition	Post-Retrofit Improvement
1	Roofs	Pitched roof, 50mm insulation	250mm of mineral wool insulation with ventilation
2	Walls	Solid walls	100-120mm external insulation
	Floors	Solid floors	Insulated floors
3	Windows	Single glazed	Double glazed, low E argon filled
	Doors	Solid timber	Insulated wooden/PVC doors
4	Heating system upgrade	Central heating oil boiler; 85% efficiency	Heat pump; 350% efficiency

The same approach described in the pre-retrofit analysis (section 2.2.1.5) was taken for the retrofitting process of each house type, with the latter employing updated U-values on the same HTC and heating demand equations, to account for the energy efficiency improvement resulting from the retrofit. The result of this process translates into a Building Energy Rating (BER) rating, a system where buildings are ranked in terms of their energy performance from A to G scale, with

A the most efficient and G the least efficient rank. According to the data derived from the BER map (Sustainable Energy Authority of Ireland, 2024a), 28% of Aran Island’s buildings are BER-certified, with older buildings ranging between rating D and G and newer buildings having higher ratings. Figure 2.12 illustrates the BER rating classification system.

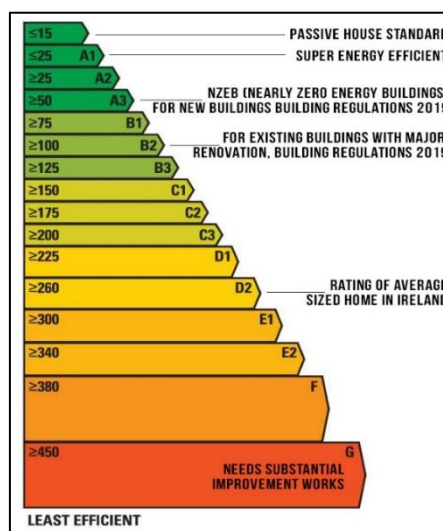


Figure 2.12. BER rating chart

2.2.1.7 Estimating energy savings and CO₂ reduction

Using conversion factors derived from the guidelines for improving energy efficiency in traditional buildings shown in Figure 2.13, the CO₂ emissions reductions associated with each house type were calculated to demonstrate the potential environmental benefits that come along with retrofitting each house type.

Fuel	Emissions gCO ₂ /kWh
Wood logs	25
Woodchips/pellets	25
Biomass or biogas	25
Biodiesel from renewable sources only	47
Bioethanol from renewable sources only	64
Mains gas	203
Electricity	224*
LPG (propane or butane)	232
Heating oil	272
House coal/anthracite	361
Solid multi-fuel	369
Sod peat	375
Manufactured smokeless fuel	392

Figure 2.13. Carbon dioxide emissions by fuel type (Government of Ireland, 2023)

The energy savings from each house type were then determined by comparing the pre-and post-retrofit heating demands according to the following equation.

$$\text{Energy Savings(\%)} = \frac{(\text{Pre retrofit Consumption} - \text{Post retrofit Consumption})}{\text{Pre retrofit Consumption}} \quad \text{Equation 2.4}$$

2.2.1.8 Qualitative analysis using a thermal camera

Whereas quantitative analysis was employed in the heat loss calculations for different building envelope elements, qualitative analysis through the use of a thermal camera was also employed to confirm the results. A thermal camera is a thermal inspection device that utilizes infrared imaging to evaluate the insulation performance of a building envelope. It does this by visually highlighting heat loss patterns and showing potential areas of possible concern with minimal or no insulation for targeted improvements (Hopper et al., 2012). Thermal imagery has been widely used in building assessments, and it is known to influence homeowners to adopt energy-saving measures upon seeing thermal images of their homes (Goodhew et al., 2015).

To ensure a consistent and meaningful comparison, we focused on establishing heat loss associated with window frames and glazing in our study cases presented in the results section. With the few case studies, we initially had, thermal imaging served as a liaison tool that helped increase homeowner involvement through the complimentary house insulation analysis we offered. The case studies and their findings are presented in the results section.

2.2.1.9 Spatial analysis: combining spatial data and survey results

Estimation of heating demand is crucial for improving energy management and sustainable planning. Spatial analysis has emerged as a powerful tool for assessing energy demand in building by integrating geographic, architectural, and climatic data. Nouvel et al., (2017) demonstrated its effectiveness by using 3D city models to estimate urban heating demand, highlighting its role in improving energy simulations and decision-making. Mapping building characteristics and its energy demand allows researchers to analyse heating demand patterns, reduce heat loss, and optimize energy supply.

However, in the case of Aran Island, this study relied on open-source data refined through direct surveys. OpenStreetMap (OSM) building footprint data was used to determine floor and roof areas and identify residential buildings. To enhance accuracy, field surveys in two CSO Small Areas of Inishmore (067110006 and 067110005) gathered missing details such as building storeys, occupancy status, and building types were recorded. The data collected was then processed using Microsoft Excel and ArcGIS Pro.

After analysing the survey results from the two CSO small areas, it was found that building type and footprint size were not strongly correlated, as shown in the regression analysis in the Table 2.4. This indicates that each house type had a wide range of floor sizes.

Table 2.4. Regression correlation results

	No. of storeys	Typology
No. of storeys	1	
Typology	-0.11	1
Footprint Area	-0.02	0.30

To improve accuracy and account for variations in housing floor sizes, the energy demand for all surveyed buildings was calculated by multiplying the demand rating from Section 2.1.1 by each building's footprint area, assumed to represent the internal floor area, based on its building type. The heat demand for each house was then determined using Equation 2.5.

$$\text{Heat Demand} \left(\frac{kWh}{\text{house. year}} \right) = \text{Area (m}^2\text{)} \times \text{Storey} \times \text{Demand rating} \left(\frac{kWh}{\text{m}^2} \right) \quad \text{Equation 2.5}$$

To determine the average energy demand for each house type in the surveyed area, Equation 2.6 was applied. The average heating demand for each house was adjusted based on the fact that residents usually turn off their fossil-fuelled heating systems when they are away, such as at work. Therefore, we assume that the fossil heating system operates for only 16 out of 24 hours,

even though the building still requires heat. Whilst, when the heating system converted to the heat pumps, the factor did not apply as the heat pumps will keep operated.

$$\text{Average heat demand} \left(\frac{\text{kWh}}{\text{house} \cdot \text{year}} \right) = \frac{\text{Total heat demand} \left(\frac{\text{kWh}}{\text{year}} \right)}{\text{Total number houses}} \times \text{behaviour factor} \quad \text{Equation 2.6}$$

The total energy demand for the three islands, categorized by house type, was estimated by combining the average demand per house type from the surveyed areas with CSO housing distribution data, segmented by construction period. This method facilitates a simplified estimate of the island's total occupied housing energy demand. The total heat demand for each house type was then calculated using Equation 2.7.

$$\text{Total Demand} \left(\frac{\text{kWh}}{\text{year}} \right) = \text{Average heat demand} \left(\frac{\text{kWh}}{\text{house} \cdot \text{year}} \right) \times \text{number of house} \quad \text{Equation 2.7}$$

2.2.1.10 Scenario development

This study explores the heating demand across three different scenarios, each representing a various approach to retrofitting and heating systems on the Aran Islands. The scenarios aim to evaluate the impact of transitioning from current heating system to heat pumps to the overall heating demand to support Aran Island sustainable goals on the heating sector.

The three scenarios considered were:

- **Scenario 1:** Current state. This scenario reflects current state in Aran Island with 50 heat pumps installed.
- **Scenario 2:** 50% Heat pumps – assumes 50% of houses are retrofitted and with heat pumps installed, including all Type 1 houses and 60% of Type 2.
- **Scenario 3:** 100% Heat pumps – assumes all houses are retrofitted with heat pumps.

To evaluate the impacts of each scenario, the electricity consumption for heat pumps was distributed using a heating load curve pattern obtained from Staffell et al., (2023). The curves were normalized to represent energy consumption in Aran Island. To represent additional demand from hot water due to shifting to heat pumps, the curve was adjusted to account for additional electricity needed for water heating. Based on SEAI data (2019), water heating demand is approximately 1,500 kWh per household annually, assuming a daily hot water consumption of 125L/p/day. Load curves were adjusted using temperature data from NSRDB to meet a typical hot water temperature of 45°C. However, it must be noted that for hygiene reasons, water must be periodically heated to 60°C to prevent Legionella bacterial growth (CDC, 2025).

2.2.1.11 Cost-benefit analysis

The Aran Islands are at the forefront of Ireland's transition to clean energy, driven by a shared vision of sustainability and carbon neutrality (Aran Islands energy co-operative, 2018). With backing from the Sustainable Energy Authority of Ireland (SEAI) and the Aran Islands Energy Cooperative (CFOAT), extensive efforts have been made to reduce dependency on fossil fuels and enhance energy efficiency. This chapter delves into the economic analysis of proposed retrofitting solutions for different house types on the Islands, examining the costs, benefits, and payback periods associated with different scenarios.

The cost-benefits analysis focuses on six categories of houses undergoing four levels of retrofitting, ranging from Step 1 to Step 4. Each retrofitting step involves varying costs and projected payback periods for each scenario. The analysis uses 2014 Tabula data as reference and has been adjusted to 2024 values using the Consumer Price Index (CPI) to reflect current costs accurately. It is important to note that since the Tabula 2014 brochure has not been updated, the Better Energy Homes Grants program is used as our reference to estimate the cost of heat pumps.

The Better Energy Homes Grants program is considered for this economic analysis. This grant scheme offers homeowners the flexibility to manage their own home energy upgrades through a step-by-step approach, allowing them to carry out different upgrades over time and within their budgets. Applicants select an SEAI registered contractor and apply for the grant through an online application system. The grant is paid directly to the applicant or the contractor once the necessary forms are completed and submitted. This approach is suitable for those considering one or more energy upgrades. Specific island homeowners are entitled to additional grant support, making it an excellent opportunity for those living on the Aran Islands to benefit from financial assistance for retrofitting projects. It's important to note that while grants for windows and doors are available under the One Stop Shop service, they are not included in the Individual Energy Upgrades option (Sustainable Energy Authority of Ireland, 2024).

2.2.2 Sociotechnical analysis of retrofitting and transition to renewable heating

To strengthen community engagement, which is one of the primary objectives of our research, we aimed to develop a comprehensive understanding of the current housing conditions and the heating methods used by residents. Our outreach efforts focused on engaging as many residents as possible through various channels.

One approach involved direct interaction with the community by visiting commercial establishments such as markets, souvenir shops, and bars. During these visits, we introduced ourselves, explained our research objectives, and outlined the purpose of our presence on the island. This method generated interest, with some residents voluntarily arranging interviews.

A more effective strategy was facilitated by CFOAT, which distributed our online survey via email. Since CFOAT had pre-existing contacts with residents interested in solar rooftop installations and grant applications, they reached out to them, inviting them to participate in the survey. Additionally, residents were asked if they would be open to sharing their contact details for a potential face-to-face interview. This approach proved successful, as CFOAT is a well-established entity within the community, making residents more receptive to engagement. As a result, we secured half of the total survey responses through this method, with two individuals expressing interest in face-to-face interviews.

Furthermore, we organized a community event at a well-known venue frequently used for gatherings. This initiative led to an arranged interview with a resident who was keen to learn more about heating systems and retrofitting. As part of our engagement, we also conducted a thermal camera scan of their home, assessing insulation levels and identifying areas of significant heat loss. CFOAT also recommended promoting a free thermal scan as an incentive to encourage community members to participate in the interviews.

The advertisement played a crucial role in connecting us with numerous residents interested in receiving a thermal scan and discussing their home insulation, construction materials, and heating methods. Additionally, it allowed us to assess their willingness to upgrade heating systems to heat pumps and gauge their satisfaction with their current heating systems.

Our inquiries focused on the materials used for roofs, walls, floors, and windows to evaluate insulation levels. Furthermore, we collected data on the construction dates of homes to better understand their age, insulation status, and any past retrofitting efforts. By conducting surveys and in-person interviews, we aimed to gather valuable insights into residents' experiences and perspectives on heating methods. This “people-to-people” feedback is essential for understanding the social dimensions of the island’s energy transition. A successful transition to greener and more efficient heating alternatives depends on the willingness of the community to adopt these changes.



Figure 2.14. Interview with an island inhabitant



Figure 2.15. Thermal assessment promotion

In the scenario analysis section 2.2.1.10, three scenarios have been shown. One of the key factors influencing which scenario will unfold is the community's readiness to embrace sustainable solutions.

Our research aims to evaluate residents' perceptions of their homes and their openness to retrofitting, while also identifying potential barriers and challenges they face in upgrading their heating systems. By listening to their experiences, we integrate both qualitative and quantitative analyses. To ensure comprehensive insights, we actively engaged with as many participants as possible through surveys and interviews. The results reflect a spectrum of opinions on sustainable and energy-efficient housing.

2.2.3 Results

2.2.3.1 Retrofitting and its impacts

This section presents a summary of the energy savings and CO₂ emissions reductions for the different house types, highlighting the impact of retrofitting across the three scenarios considered in this study.

a) Energy demand and savings

Table 2.5 below presents the pre- and post-retrofit energy demands for each house type. The retrofit, as earlier discussed involved improvements in the U-values of walls, roofs, floors, windows, and doors, leading to reduced energy demands. For example, House Type 1 shows a significant reduction in energy demand from 34,834kWh/year to 11,596kWh/year, a decrease of approximately 67%. Similarly, House Type 2 exhibits a reduction from 20,273kWh to 6,856kWh/year, reflecting an energy savings of 66%.

Table 2.5. Pre-retrofit and post-retrofit U-values and energy demands for each house type

House Type	Pre-Retrofit						Post-Retrofit					
	U-value Walls	U-value Roof	U-value Floor	U-value Windows	U-value Doors	Energy Demand (kWh/year)	U-value Walls	U-value Roof	U-value Floor	U-value Windows	U-value Doors	Energy Demand (kWh/year)
1	2.1	0.68	0.65	4.8	3	34,834	0.27	0.13	0.65	1.4	1.4	11,596
2	1.78	0.68	0.65	5.7	5.7	20,273	0.29	0.13	0.65	1.4	1.4	6,856
3	0.55	0.41	0.26	2.8	3	10,314	0.37	0.13	0.26	1.4	1.4	5,944
4	0.55	0.26	0.41	2.8	3	17,389	0.55	0.2	0.41	1.4	1.4	14,459
5	0.37	0.2	0.34	2	3	9,331	0.37	0.2	0.34	2	3	9,331
6	0.37	0.2	0.34	2	3	15,633	0.37	0.2	0.34	2	3	15,633

On the contrary, House Types 5 and 6 show no reduction in energy demand upon retrofitting, and their U-values remain the same. This suggests that the materials and construction methods of these houses were already sufficiently efficient, resulting in no further reductions in energy demand.

b) CO₂ emission reductions

The reductions in CO₂ emissions positively correlate with energy savings in each house type. As shown in Table 2.6, House Types 1 and 2 achieve CO₂ emissions reductions of 72.6% and 72.1% respectively, which aligns with their large reduction in energy demand. House Type 3 saves 52.5% of CO₂ emissions, in line with a 42% saving in energy demand. However, House Types 5 and 6 do not report any changes in CO₂ emissions due to a lack of changes in their energy demand.

Table 2.6. Energy savings and CO₂ emissions reductions associated with retrofitting

House Type	Energy Savings with Heat Pumps (%)	CO ₂ emissions reduction (%)
1	67	72.6
2	66	72.1
3	42	52.5
4	17	31.5
5	-	-
6	-	-

c) Retrofitting scenarios

The retrofitting scenarios were created to represent the effects of different levels of retrofitting on energy consumption. As explained in section 2.2.1.10, scenario 1 (Business as Usual), assumes no retrofitting, and all the six house types maintain their pre-retrofit energy consumption. House Type 2 has the highest consumption of 181.01 kWh/m²/year, followed by House Type 1 at 158.34 kWh/m²/year.

Scenario 2 assumes a full retrofit for House Type 1 and a partial retrofit for House Type 2 houses, leading to a significant energy consumption reduction of 52.71 kWh/m²/year for House Type 1 and 61.21 kWh/m²/year for House Type 2. All the other house types retain their pre-retrofit consumption. This highlights the greater need for retrofitting in old houses compared to newer ones.

Scenario 3 represents a full retrofit across all house types, with a 100% penetration of heat pumps, achieving the lowest energy consumption values for all the house types.

Table 2.7. Retrofitting scenarios considered in this study

House Type	Scenario 1 (kWh/m ² /year)	Scenario 2 (kWh/m ² /year)	Scenario 3 (kWh/m ² /year)
1	158.34	52.71	52.71
2	181.01	61.21	61.21
2	181.01	181.01	61.21
3	88.16	88.16	50.80
4	62.10	62.10	51.64
5	61.80	61.80	61.80
6	53.17	53.17	53.17

The scenarios demonstrate the effectiveness of heat pumps while acknowledging the necessity of employing a balanced and realistic approach to prioritize older houses for retrofitting compared to newer ones.

2.2.3.2 Findings from thermal imaging

The findings from thermal imaging are presented in the case studies below.

Case study 1

Our first thermal imaging case study was a house whose owners reported cold spots around three of their windows. The thermal images confirmed heat loss at the corners of these windows, while other windows were in good condition.

Figure 2.16 below compares one of the problematic windows with a well-performing window in the same house. The thermal images, with a temperature range of (10°C) to (18°C) revealed heat loss patterns. The coldest areas, represented in dark blue (10°C), contrasted sharply with warmer spots in red/white (18°C). This pattern was consistent across all three problematic windows, suggesting heat loss through gaps, likely due to poor installation.

As a short-term solution, we recommended draught proofing to minimize heat loss, however for the long term, proper reinstallation of these windows is necessary to improve energy efficiency and indoor comfort.

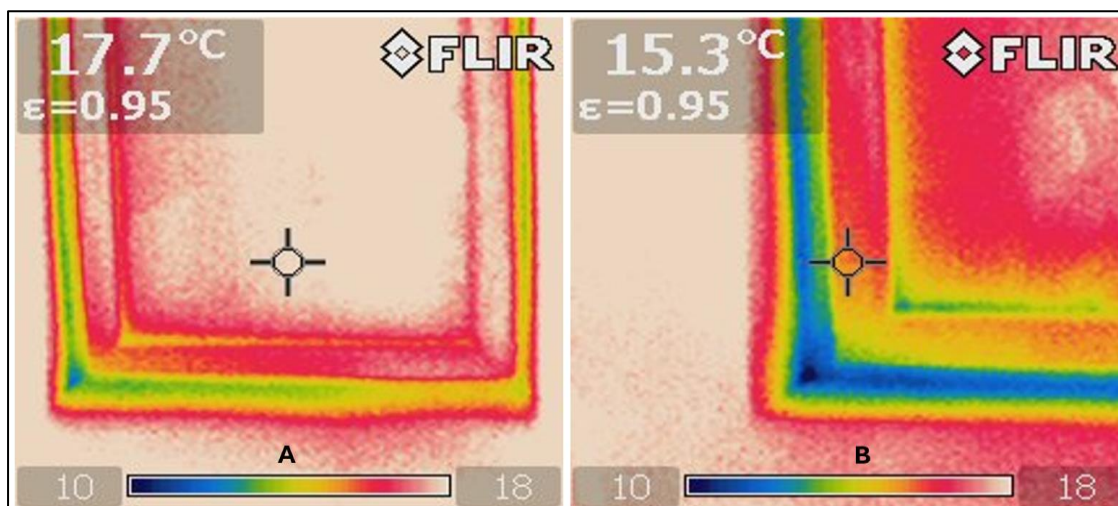


Figure 2.16. Cold spots around: A. insulated window and B. non-insulated window

Case study 2

This case study aimed at demonstrating the difference between double-glazed and triple-glazed windows. The thermal image was taken from outside a house in Inis Mor, and it showed a double-glazed window appearing warmer than the triple-glazed one, indicating that it emitted more heat. The windows were analysed on a similar scale of (7°C) to (12°C).

In a discussion with the house owner, he confirmed the glazing on each window and mentioned his plans to replace all windows with triple glazing. This observation was in agreement with the quantitative analysis, which showed that triple glazing has a lower U-value which is equivalent to improved insulation compared to double glazing.

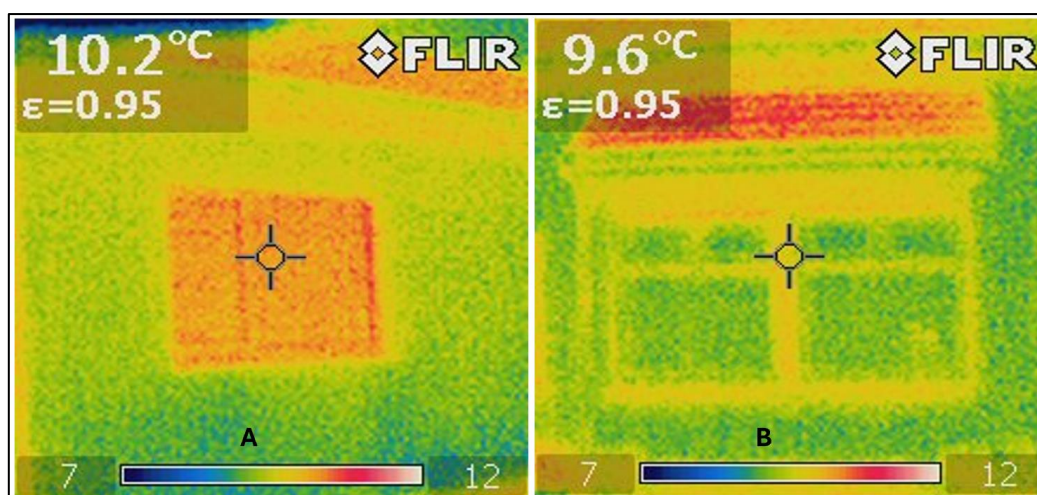


Figure 2.17. Comparison between: A. double-glazed window and B. triple-glazed window

2.2.3.3 Heat demand of the Aran Islands

2.2.3.3.1 Heat demand in small areas of Inishmore

The housing stock on the Inishmore shows various building styles distributed across different parts of the Island. The survey results showed that most buildings fall under house 2 type followed by type 1 houses. The results were in agreement with CSO statistics for the entire Aran Islands, showing a 1–6% variation between the survey findings and the data on housing mix based on the year of construction. This slight discrepancy may be caused by the exterior appearance of some houses does not accurately reflect their construction period. The result and comparison presented in the Table 2.8.

Table 2.8. Survey result compared to CSO statistics

Data source: (CSO, 2022)

House type	Built year (Estimated)	Survey result (2 small area districts of Inishmore)		CSO statistics (Aran Islands)	
1	1900-1920	39	23%	84	17%
2	1920-1980	67	40%	204	41%
3	1981-1990	13	8%	70	14%
4	1990-2000	10	6%	56	11%
5	2001-2010	26	16%	56	11%
6	2011-Now	11	7%	32	6%

Although it was relatively easy to categorize buildings into defined typologies during the survey, challenges arose in determining the occupancy status of some properties. Only clear signs of abandonment, such as ruined structures, broken windows, or overgrown vegetation, were used to identify unoccupied buildings. Consequently, the survey's accuracy may be limited, as it was not possible to verify the status of every house in detail. As surveyed pattern type in general represent the building stocks in the Island, heating energy demand then estimated using its OSM building footprint area, storey data, house type, and energy rating. The result presented in the

Table 2.9.

Table 2.9. Total houses surveyed and their energy demand

Data source: (OpenStreetMap contributors, 2025)

House type	Number of houses	Average total floor area (m ²)	Average heat demand (kWh/year)
1	39	201	11,400
2	67	113	13,500
3	13	135	6,900
4	10	240	5,800
5	26	163	9,300
6	11	248	8,100
Average			11,000

The calculation results show that the average space heat demand for the two Inishmore small areas are 11,000 kWh/house/year. Among the building types, the older type, particularly type 2 followed by type 1, accounted for the highest energy demand in heating. In contrast, newer houses had lower energy demand due to better energy efficiency when they were constructed. Comparing the Aran Island 2018 Energy Masterplan report, which recorded an average fossil fuel consumption of 13,300 kWh per house in Inishmore, or around 11,300 kWh/year of heat demand assuming system efficiency of 85%. The calculation has already accounted for the behaviour of residents on the Aran Islands when using fossil fuel heating. While at work or away from home, residents typically turn off their heaters. Therefore, a factor accounting for an eight-hour daily heating shutdown has been incorporated into the calculation.

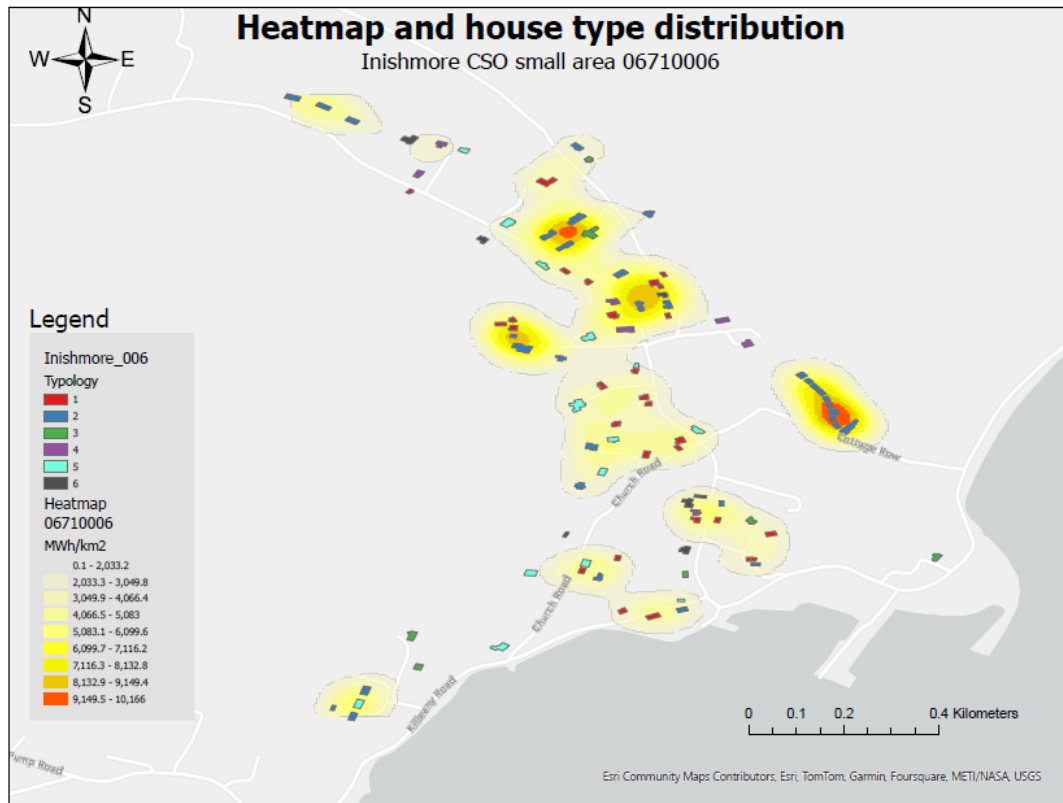


Figure 2.18. Building typology distribution and heatmaps on Inishmore 006 electoral area

The average energy demand for each building typology from the survey was used as a benchmark to represent the energy demand of similar house types across the entire island. The energy demand results then used to generate heatmap for the island. A sample of building type spatial distribution and heatmap for area of Inishmore CSO small areas 067110006 presented in the Figure 2.18.

2.2.3.3.2 Heat demand in Aran Islands

2.2.3.4 Heat demand for space heating

This study estimated the Aran Islands space heating energy demand for by combining data from surveyed area with CSO housing statistics. To improve accuracy, it considered building types and construction periods. The estimation was done by calculating the average energy demand per building type and applying it to the CSO housing distribution data. This approach ensured a simplified method to estimate of the island's energy demand. The results, presented in Table 2.10, explore three scenarios, demonstrating how energy efficiency measures can significantly reduce demand and reach the Island sustainability goals.

The estimation indicated a total energy demand of 5,198.3 MWh for the entire island in Scenario 1, with the largest share attributed to house type 2, followed by house type 1. House type 2 contributes the highest demand due to its large number and lower energy efficiency compared to other houses on the island. In Scenario 2, energy demand decreases to 4,310.4 MWh as a result of retrofitting efforts applied to house type 1 and 60% of house type 2 to allow 50% of heat pumps installation. Finally, in Scenario 3, where all houses are assumed to be retrofitted and equipped with heat pumps, demand drops to nearly half of Scenario 1, reaching 3,491.4 MWh. An unusual pattern is observed in house type 4, where the energy demand in scenario 3 is actually higher than in scenario 2, despite retrofitting being implemented. This discrepancy is attributed to the eight-hour heating shutdown factor applied when estimating fossil fuelled houses. However, after retrofitting and installing heat pumps, the heating system operates continuously whenever the temperature drops, eliminating the influence of the behavioural factor in this case.

Table 2.10. Housing stocks and energy consumption calculation result

House type	Space heat demand (MWh)		
	Scenario 1	Scenario 2	Scenario 3
1	957.8	478.3	478.3
2	2,762.3	2,235.2	1,401.2
3	484.0	484.0	418.4
4	325.9	325.9	406.5
5	406.2	524.9	524.9
6	262.1	262.1	262.1
Total	5,198.3	4,310.4	3,491.4

To validate these results, data from the 2018 Energy Masterplan on fossil thermal fuel demand in the residential sector for the Aran Islands was used. The plan provides data for Inishmaan and Inishmore, while demand for Inisheer was estimated based on average demand. This comparison was conducted to assess the reliability of the estimates, with the results presented in the Table 2.11.

According to the Table 2.12, the difference between calculated energy demand and the actual demand is 2.95%, assumed similar weather condition. This difference is relatively small, especially considering the complexity of building energy estimation and the various uncertainties that affect real energy consumption. Factors contributing to discrepancies between actual and

modelled energy use include the accuracy of weather data, as variations in temperature, wind, and sunlight can impact heating demand. Additionally, occupant behaviour, such as heating habits or ventilation practices, can significantly influence energy use. Errors in data collection, such as mistakes during surveys or inaccurate building information, can also cause differences. It is common for real and modelled energy demand to vary. Herrando et al., (2016) observed that the average energy performance gap for buildings is around 30%. Compared to these findings, the 2.6% difference in our analysis is well below the 30% threshold reported by Herrando et al., (2016) indicating that the model provides a reasonably accurate representation of actual energy demand for the building.

Table 2.11. Validation of result

Category	Heat demand (MWh)	Source
Total residential heat demand	5,049	Energy Masterplan, 2018 (Adjusted to account Inisheer)
Calculated residential heat demand	5,198	
Difference	2.95%	

To estimate the final energy demand which account for the heating system efficiency, the final energy demand based on fossil fuel and electricity demand calculated. The result presented in the Table 2.12.

Table 2.12. Space heating final energy demand

Source	Space heating final energy demand (MWh)		
	Scenario 1	Scenario 2	Scenario 3
Fossil	5,609	2,944	-
Electricity (Heat pumps)	123	517	998

The analysis of final energy consumption and demand in the Table 2.12 highlights the shift in energy sources across three scenarios. In Scenario 1, the business-as-usual case, fossil fuel consumption is highest at 5,608.8 MWh, with electricity use from heat pumps at 123.0 MWh. Scenario 2, assuming 50% heat pump adoption, significantly reduces fossil fuel consumption to 2,944.1 MWh while increasing electricity demand to 516.5 MWh. In Scenario 3, representing full heat pump adoption, fossil fuel use is eliminated, and electricity demand rises to 997.5 MWh. The total final energy only around one fifth of scenario 1 final energy demand. These findings showed that adopting heat pumps could greatly reduce reliance on fossil fuels and shift energy demand toward electricity. Since heat pumps operate more efficiently than fossil fuelled heating systems, with a higher system efficiency, it required less energy to produce the same amount of heat. As a result, the total energy demand decreased significantly, demonstrating the potential benefits of transitioning to cleaner heating technologies.

2.2.3.5 Heat demand for hot water

The transition from oil fuelled central heating to heat pumps not only shifts energy demand for space heating but also for hot water production. In current systems, oil boilers provide both heating and hot water. When switching to heat pumps, the demand moves from fossil fuels to electricity, altering the overall load profile. This shift has implications for peak electricity demand, energy management strategies, and system integration, making it essential to understand how hot water demand adapts within decarbonized scenario of heating solutions. In addition to that, demand for hot water behaves differently from space heating, as it remains necessary even during the summer months. The heat demand of water heating presented in the Table 2.13.

Table 2.13. Hot water final energy demand

Source	Hot water final energy demand (MWh)		
	Scenario 1	Scenario 2	Scenario 3
Fossil	798	510	-
Electricity	21	108	215

2.2.3.6 Total heat demand

Total heat demand consists of space heating and hot water heating requirements, both components must be considered for a better accuracy assessment of overall heat demand assessment. The result of total final heat demand of Aran Island across 3 scenarios shown in the Table 2.14.

Table 2.14. Total final energy demand of space heating and hot water

Source	Total final energy demand (MWh)		
	Scenario 1	Scenario 2	Scenario 3
Fossil	6,407	3,454	-
Electricity	145	624	1,213

2.2.3.7 Resulting CO₂ emissions

Carbon emissions are a crucial factor to evaluate when implementing energy efficiency measures and introducing green heating technologies, such as heat pumps. Assessing emissions helps determine the effectiveness of these improvements in reducing reliance on fossil fuels and lowering overall carbon footprint. Analysing the effects of retrofitting and heat pump adoption helps clarify their role in meeting the Aran Islands' decarbonization goals. The results of carbon emissions across 3 scenarios were presented in the Table 2.15.

Table 2.15. Emission from final energy consumption in residential heating

Emission	CO ₂ emissions (tons/year)		
	Scenario 1	Scenario 2	Scenario 2
CO ₂ Emission	1,830	1,050	204

According to the results above, in Scenario 1, where reflects the current state in Aran Islands, CO₂ emissions were 1,829.78 tonnes annually due to the heavy reliance on fossil fuels for heating. In Scenario 2, emissions dropped significantly to 1,050.23 tonnes after retrofitting older houses and equipped it with heat pumps, which improved insulation and reduced energy consumption. In Scenario 3, where all houses were fully retrofitted and equipped with heat pumps, emissions further decreased to almost one tenth of scenario 1 at 204.36 tonnes, demonstrating a substantial shift away from fossil fuels. These findings highlighted the effectiveness of retrofitting and electrification in reducing CO₂ emissions, emphasizing the potential of heat pumps in achieving low-carbon residential heating in the Aran Islands.

2.2.3.8 Resulting electrical load profile of heat pumps

An hourly load profile for heat pumps provides a detailed breakdown of energy demand over the course of a year, typically reflecting the heating demand for a building or system. This profile is essential for understanding how heat pumps operate, their energy efficiency, and their performance throughout varying conditions such as temperature fluctuations and usage patterns. It helps to identify peak demand times, assess operational efficiency, and optimize the system's performance to maintaining the desired indoor comfort levels.

The Figure 2.19 illustrates the load curve for the scenario with 50% heat pumps. In this scenario, the peak load occurs towards the end of January, reaching a maximum of approximately 180 kW.

This peak is primarily due to the increased heating demand during the colder winter months when outdoor temperatures are lower, necessitating more energy consumption to maintain indoor comfort levels.

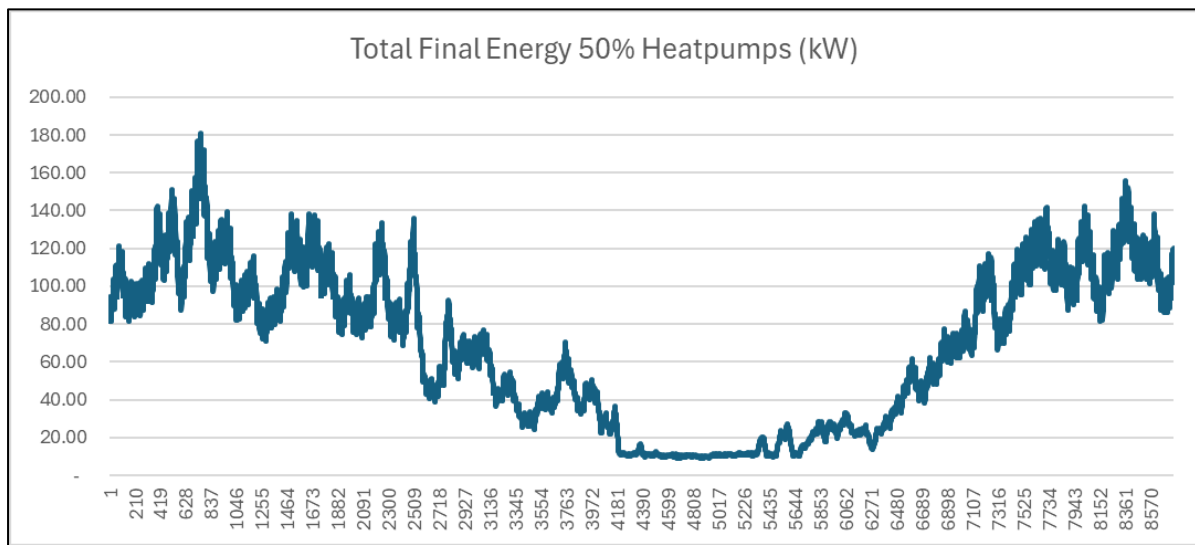


Figure 2.19. Scenario 2: 50% heat pumps annual load profile

During the summer months, the load curve flattens, reflecting a reduced need for heating. However, it never reaches zero, indicating that the heat pumps are still operating, albeit at lower levels. This persistent demand is mainly attributed to the water heating requirements, which are essential year-round. While the heating demand for space heating significantly decreases in summer, the heat pumps continue to operate to meet the constant need for hot water, thereby indicating that the system remains in operation even during the warmer months.

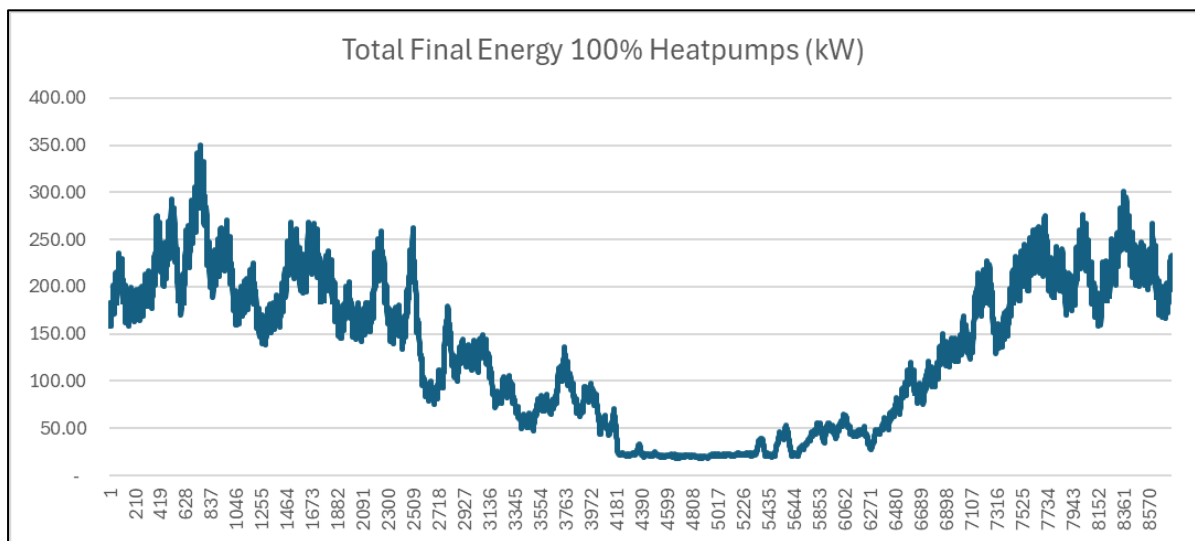


Figure 2.20. Scenario 3: 100% heat pumps annual load profile

Compared to Scenario 2, the load curve analysis for Scenario 3 in the Figure 2.20 shows the same pattern, with both scenarios exhibiting comparable overall trends. The key difference lies in the peak demand, where Scenario 3 reaches a higher load of 350 kW. This increase in peak demand can be attributed to the higher proportion or capacity of heat pumps in Scenario 3, requiring more energy during peak heating times. Despite the similar usage pattern, the greater demand in Scenario 3 highlights the impact of scaling up the heat pump system on the overall energy consumption and perhaps the grid ability to provide the load during the peak time.

2.2.3.9 Community engagement: findings from community to retrofitting and heat pumps adoption

In the appendices, you can find detailed survey results, where we have got 11 responses from residents.

Since survey responses were not at least 5% of the population (43 people) on the island, we considered that data is not representative enough and we depended on statistical data available for the island which is considered more accurate and representative. But we used this data for comparison and validation of some old statistical data. These interviews were also analyzed to know the social aspect of the study but not included in the calculation of the modelling aspect.

Challenges for retrofitting and renewable heating

Through discussions with residents and listening to their experiences on the island, we explored the challenges preventing them from retrofitting their homes or transitioning to heat pumps. Several key factors emerged as age of residents, house ownership, cost and workforce availability, reliability and personal preferences.

1. Age as a barrier

For some older residents, retrofitting their homes is not a priority, as they have lived in their houses for many years and are resistant to making significant changes. Many perceive such investments as unnecessary at their stage of life. However, some of the older residents expressed willingness to make improvements if the process were simple, cost-effective, and capable of enhancing comfort.

2. House ownership

Ownership of the houses plays a barrier for retrofitting homes as some of the residents stated that they would consider investing in a new heating system, such as a heat pump, only when they move to the house they own. Until then, it is viewed that such upgrades are an unnecessary expense, as heating oil adequately meets the residents' current needs.

3. Cost and workforce availability

The financial burden of retrofitting, coupled with a shortage of skilled local workers, poses a significant challenge for residents seeking home improvements.

4. Perceived unreliability of electric heating

Several residents cited concerns about the reliability of electric heating, particularly in the effects of a recent storm. Power outages lasted between three to seven days in different areas, depending on the severity of damage to transmission lines. This experience has reinforced skepticism regarding the feasibility of fully electrified heating solutions. Also, there is a growing belief in having more than one heating system in the house.

That returns to their experience during the storm in which power outages lasted between three to seven days in different areas, depending on the severity of damage to transmission lines. This experience has reinforced skepticism regarding the feasibility of fully electrified heating solutions.

5. Personal preferences: comfort, aesthetic, and durability

Few of the residents expressed a strong preference for a wood-burning stove, describing it as a cozy and comforting heating solution that aligns with the peaceful and rustic lifestyle they seek on the island. Another resident raised concerns about heat pumps, fearing they might be prone to rust and deterioration, leading to potential reliability issues over time. Since the island has severe corrosion, sea water corroding iron research.

These insights highlight the diverse factors influencing residents' decisions regarding home energy upgrades, emphasizing the importance of addressing financial, technical, and personal considerations in promoting sustainable heating solutions.

2.2.3.10 Cost-benefits analysis of proposed retrofitting solutions

The below table gives an overview of the total estimated cost before and after the grant is applied to a single house. The retrofitting solution proposed in the section 2.2.1.6 for the specific type of houses and their associated cost has been considered. Please note that grants for windows and doors are not available under the Individual Energy Upgrades.

Table 2.16. Types of houses and associated costs per house

Data source: (Tabula, 2024)

	Estimated Total Cost (2024)	Total Grant Available	Total Cost after Grant
Type 1	€53,841	€16,000	€37,841
Type 2	€35,738	€16,000	€19,738
Type 3	€18,394	€16,000	€2,394
Type 4	€16,923	€8,000	€8,923
Type 5	€16,341	€8,000	€8,341
Type 6	€16,341	€8,000	€8,341

Sample data analysis: Type 1-detached house, stone walls, pre 1900 -2 storey

For illustration, a Type 1-Detached House, stone walls, pre 1900 -2 storey undergoing all four retrofit steps is analysed. The total estimated cost for retrofitting the sample house in 2024 prices is €53,841, with a €16,000 grant amount which can be applied, bringing the total retrofitting to €37,841. Table below provides a detailed cost break-down of each step and their respective grant amount through “The Better Energy Homes Grants program”.



Figure 2.21. Type 1- detached house, stone walls, pre 1900 -2 storey

Table 2.17. Types of houses and associated costs per house

Data source: (Tabula, 2024)

Steps of Retrofitting		Estimated Cost (2024)	Grant	Cost After Grant
Step 1	Roof Insulation	€1,616	€1,500	€116
Step 2	Wall Insulation	€30,289	€8,000	€22,289
Step 3	Windows and Door replace	€6,337	-	-
Step 4	Heating system replace	€15,600	€6,500	€9,100
Total		€53,841	€16,000	€37,841

2.2.3.10.1 Analysing the cost of each scenario

To further explore the economic impact of retrofitting solutions, three scenarios were analysed: BAU scenario, 50% Heat pumps scenario and 100% Heat pumps Scenario. With reference to section 2.2.1.6, the below table summarizes the cost of retrofitting based on different house type.

As stated in section 2.2.1.10, scenario 1 is a BAU condition therefore no retrofitting cost is considered. While scenario 2 undergoes 100% retrofitting for type 1 and type 2 including 38 Heat pumps to type 5 houses. The cost that has been estimated to complete this retrofit is around 5 million euro for 201 houses.

Additionally, scenario 3 will aim to retrofit type 1 - type 4 houses and provide heat pumps to 38 houses in type 5. The total cost of this scenario will be around 8 million euro for 452 houses. The below table summarizes the estimated cost for each scenario.

Table 2.18. Retrofitting cost of each scenario

House Type	House stock	Scenario 2 Cost/House	Scenario 2 Total Cost	Scenario 3 Cost/House	Scenario 3 Total Cost
1	84	€37,841	€3,178,682	€37,841	€3,178,682
2	79	€19,738	€1,559,328	€19,738	€1,559,328
2	125	-	-	€19,738	€2,467,291
3	70	-	-	€2,394	€167,602
4	56	-	-	€8,923	€499,665
5	38	€9,100	€345,800	€9,100	€345,800
5	18	-	-	-	-
6	32	-	-	-	-
Total	502	€66,680	€5,083,810	€97,735	€7,872,568

Total Heating and Retrofit Cost

As stated in section 2.2.3.6, the annual heating energy consumption in scenario 1 is 6551 MWh with 6,406 MWh through fossil fuel and 144 MWh from electricity. Further breaking down the fossil fuel consumption, we have 5,021 MWh based on oil, 51 MWh wood, 965 MWh coal, 17 MWh peat and 13 MWh LPG. Furthermore, scenario 2 and scenario 3 account for 4,078 MWh and 213 MWh of energy consumption respectively.

Using section 2.2.3.10, which provides the cost of different heating fuel types used in Aran Island, the energy costs are calculated. The cost savings when moving from BAU scenario to partial retrofit is around 0.2 million euro and to complete retrofit scenario is around 0.5 million euro per

year. The table below provides a clear comparison of the energy and retrofit costs across the three scenarios, as well as the resulting savings from implementing partial and complete retrofits.

Table 2.19. Energy Savings from each scenario

	Scenario 1	Scenario 2	Scenario 3
Energy Cost	€808,329	€608,733	€360,633
Retrofit Cost	-	€5,083,810	€7,872,568
Savings	-	€199,596	€447,696

As stated in section 3.2, the discount rate and Inflation rate considered for the economic analysis is 4% and 2% respectively. Using these input parameters, a cash flow for Scenario 2 and Scenario 3 was generated by calculating the difference between the inflows (savings) and outflows (Retrofit) over a 30-year period. In the initial period, there is a significant outflow due to the retrofit cost, resulting in a negative cash flow. As time progresses, the inflows from energy savings and offset the initial retrofit expenditure, leading to positive cash flows in subsequent periods. The accumulated cash flow is the running total of cash flow from each period.

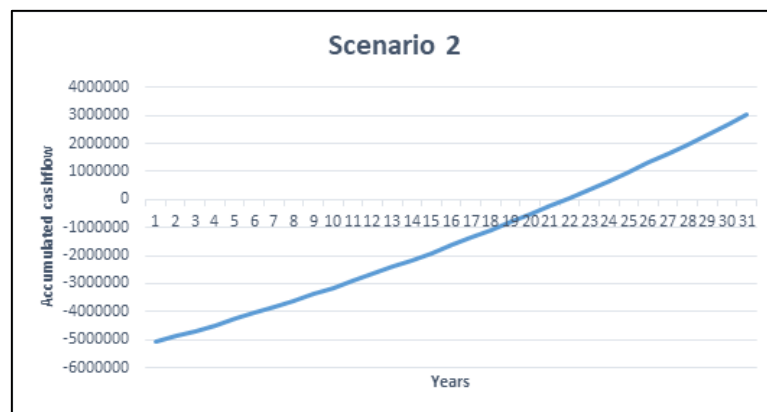


Figure 2.22. Scenario 2 cashflow

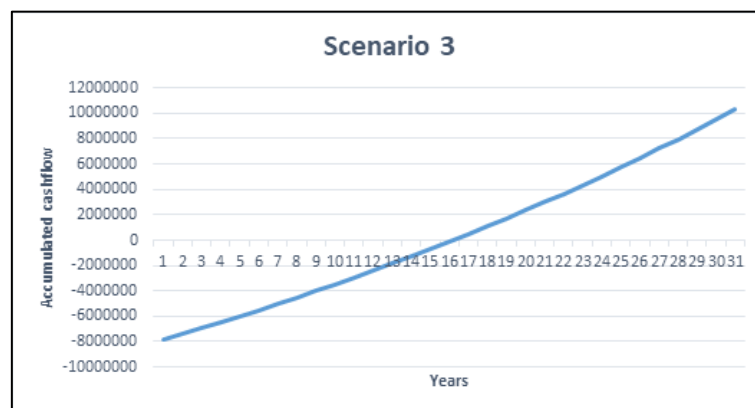


Figure 2.23. Scenario 3 cashflow

Scenario 2 has a payback period of 19 years and Scenario 3 has a shorter payback period of 13 years. While Scenario 3 requires a higher initial investment in retrofitting, the long-term savings from reduced energy consumption due to replacing the heating system with an energy efficient technology i.e. Heat pump outweigh this initial expenditure. The higher upfront cost is offset by the significant energy savings over time, resulting in a shorter payback period compared to Scenario 2.

2.2.3.10.2 Cost of energy savings

The cost of energy saving per kWh is crucial for evaluating the economic viability of energy efficiency measures compared to energy generation. It helps prioritize cost-effective solutions, guiding investment decisions for households, businesses, and policymakers. A lower cost of saving energy often means reducing demand is cheaper than producing new energy, leading to lower energy bills, reduced infrastructure costs, and improved energy security. Additionally, it supports policy design by identifying the most effective subsidies and incentives. By considering this factor, communities like the Aran Islands can optimize their transition to renewables while minimizing overall costs (IEA, 2021).

Table 2.20. Cost comparison: cost of energy saving per kWh

Type	House stocks	Pre-Retrofit heating consumption (kWh)	Post-Retrofit heating consumption (kWh)	Energy savings (kWh)	Total Retrofit Cost	Cost of energy savings per kWh
1	84	1,325,736	39,043	1,286,694	€3,178,682	€2.47
2	204	3,823,232	114,386	3,708,846	€2,467,291	€0.67
3	70	669,944	34,155	635,788	€ 167,602	€0.26
4	56	451,085	33,183	417,902	€ 499,665	€1.20
5	56	385,380	42,850	342,530	€ 509,600	€1.49
6	32	21,393	21,393	-	-	-

The cost of energy savings per kWh varies across types, with Type 1 having the highest cost at €2.47/kWh and Type 3 having the lowest at €0.26/kWh. This suggests that retrofitting older houses is more expensive per unit of energy saved compared to newer houses. Although the cost per kwh saved is higher in Type 1, these houses are likely to be retrofitted as they provide lower comfort level. Type 5 which needs Heat pump has the second highest cost of energy savings at €1.49/kWh. Type 2 and Type 3 houses build in the construction period Pre-1920 and Pre 1981 have the lowest cost of energy savings per kWh.

Sample data analysis: type 1-detached house, stone walls, pre 1900 -2 storey

The table below provides a detailed cost-saving analysis for a type 1 house, considering four standard retrofitting measures and their post-retrofit energy consumption. As stated in section (5.2.3.1), the energy consumption before retrofit is 27,431 kWh. The table shows the energy savings and cost of energy savings per kWh for each retrofitting step.

Table 2.21. Cost of energy saving: type 1

Steps	Retrofitting measures	Post-Retrofit heating consumption (kWh)	Energy savings (kWh)	Retrofit Cost (2024)	Cost of energy savings per kWh
Step 1	Roof Insulation	25,118	2,313	€116	€0.05
Step 2	Wall Insulation	11,393	13,725	€22,289	€1.62
Step 3	Windows and Door replace	9,140	2,253	€6,336	€2.81
Step 4	Heating system replace	3,313	5,827	€9,100	€1.56

Among the retrofit measures, roof insulation is the most cost-efficient, with the lowest cost per unit of energy saved (€0.05/kWh). This makes it a highly attractive option for achieving energy savings at a minimal cost. Whereas Wall insulation offers the highest energy saving (13,725 kWh) but comes at a relatively high cost per unit of energy saved (€1.62/kWh). This indicates that while it is effective in reducing energy consumption, it may not be the most economical choice. Heating system replacement provides moderate energy savings of 5,827 kWh with a cost per unit of energy saved up to €1.56/kWh. This measure strikes a balance between cost and energy savings, making it a viable option for retrofit projects.

To summarize, the economic benefits of retrofitting include reduced energy consumption, lower heating costs, and decreased carbon emissions. Improved insulation and energy-efficient systems lead to significant long-term savings, even though the initial investment may be substantial. This cost-benefits analysis highlights the financial implications of retrofitting homes on the Islands. By breaking down the costs and analysing the payback periods of scenarios, it provides a clear understanding of the economic feasibility of various energy efficiency improvements.

2.3 Transport

2.3.1 Mobility on the islands

The Aran Islands, which cumulatively cover approximately 46 km² have a limited road network. With a total paved road network of 41 km (OpenStreetMap contributors, 2025), it takes approximately 17 kilometres to traverse the largest island of Inishmore (Clean Energy for EU Islands, 2019). Based on the interviews conducted during the study, it was found that residents primarily use their private vehicles for daily commute and transportation of goods. According to statistics provided by CFOAT (J. Rivas et al., 2018), there are 385 vehicles on the islands with 26 of them being public minibuses and the rest private cars. The cooperative also reported that there were 25 electric vehicles (EVs) among private owners and the remaining cars on the island ran on diesel fuel.

Additionally, the islands have a public transport system that consists of private minibuses mostly used to facilitate the movement of tourists. During one of the interviews for this study, a respondent reported that most of the buses on the islands are individually owned and driven by their owners. Cycling is also a popular mode of transport for both residents and tourists. Bicycle hire services are widely available, with an increasing number of electric bikes catering to diverse preferences, as observed during this research. It was also noted that due to the islands' small size and scenic landscapes, walking and cycling is practical and enjoyable, especially during the summer season, which has the potential of reducing reliance on motorized forms of transport.

2.3.1.1 Overview of the existing transport system

Observations on Inishmore revealed a diverse range of vehicles in use. Table 2.22 below summarizes the vehicles identified during the survey and observation by visual walk-through. One notable observation was that many internal combustion engine vehicles (ICEs) were older models that would likely not be considered roadworthy on the mainland. However, given the unique conditions of the island, such as lower traffic speeds and shorter travel distances, these vehicles remain in regular use. Among EVs, the Nissan Leaf was the most observed model. While the list of ICEs is not exhaustive, the most frequently used models were also recorded. A significant trend among islanders was their preference for 4x4 vehicles, the most used ICEs on the island. While conducting the interviews, one respondent explained that vehicle taxation policies on the Aran Islands differ from those on the mainland. This is because the tax on vehicles is fixed regardless of the size of the vehicle purchased; islanders are not restricted in their choice, making it more feasible to own larger, off-road-capable vehicles. Additionally, it was noted that

many residents use their vehicles for agricultural purposes, and 4x4s are particularly useful for transporting farming equipment and supplies across the island's rugged terrain.

Table 2.22. Frequently observed vehicle models on Inishmore during the study

Private EVs	Private ICEs	Minibuses
Nissan Leaf (40 kWh)	Toyota Landcruiser Prado	Mercedes Sprinter
BMW i3 (42.2 kWh)	Mitsubishi Outlander	Ford Transit
Renault Kangoo (45 kWh)	Nissan Qashqai	VW Transporter
	Volvo XC60	
	Mitsubishi Pajero Sport	
	Toyota Hilux	
	Mitsubishi Lancer	
	VW Golf	

2.3.2 Existing grants and incentives to promote EVs

The Republic of Ireland's Climate Action Plan 2023 aims for 30% of the private car fleet to be electric by 2030 (Government of Ireland, 2024) and, as such, has various grants supporting EV purchases. Grants for private EVs can reach up to €3,500. Commercial vehicles, including light and large panel vans, have grants ranging from €3,800 to €7,600 (SEAI, 2024b). However, in the case of the Aran Islands, these grants and incentives may not apply because the vehicles purchased are typically second-hand.

2.3.2.1 Grants for second-hand EVs

SEAI grants up to €300 to purchase and install EV home charging units. This grant is available whether the homeowner owns an EV (SEAI, 2024c). However, it only supports smart chargers registered on SEAI's smart charger register. SEAI defines a smart EV charger as a device that meets specific criteria and standards outlined in their Triple E register (see SEAI, 2022). In addition to the charger grant, the additional financial incentives below apply to second-hand EV ownership.

2.3.2.1.1 VRT relief for imports

Vehicles originally registered in Northern Ireland before January 1, 2021, and imported to the Republic of Ireland are exempt from VAT. Electric vehicles can receive a VRT exemption of up to €5,000 (SEAI, 2024b).

2.3.2.1.2 Motor tax

The current motor tax for a BEV in Ireland is €120 per annum, unlike ICEs, which are between €200 and €1800 depending on your engine size and carbon emissions (Carzone, 2024).

2.3.3 Charging features on the islands

On the Aran Islands, EV owners use the standard 3-pin plugs and, in some cases, a dedicated home charger or both. The cost-effectiveness and convenience of residential charging largely drive this.

2.3.3.1 Types of chargers

EV chargers can be categorized into three main types: slow, fast, and rapid, each offering different charging speeds. AC chargers are typically used for slow and fast charging and are commonly found in homes and some public charging stations. On the other hand, DC chargers are designed for rapid charging. They are usually located along major highways and busy routes, allowing drivers to charge their batteries to about 80% in roughly 20 minutes to an hour. The time it takes to charge can vary based on the charger type and the size of the vehicle's battery. In the

Aran Islands, only AC chargers are currently in use. Given the relatively short distances, the EVs can operate without fast DC charging. Additionally, DC fast chargers require significant power, which the island's grid may not be equipped to handle without costly upgrades. Furthermore, the high installation and operational costs of DC chargers make them impractical for the limited number of EVs on the islands. Table 2.23 outlines the various types of EV chargers and their characteristics.

Table 2.23. EV Charger Types (AC)

Charging Level	Connector Type	Typical Power Output	Common Use Cases
Level 1 (Slow Charging)	Type 2 (via Mode 2 cable)	2.3 kW (230V, 10A)	Emergency home charging via a standard 3-pin socket (Schuko or BS 1363)
Level 2 (Fast AC Charging)	Type 2	3.6 kW (16A, 230V)	Home wall box (slower units), some public charge points
		7.4 kW (32A, 230V)	Home chargers, most public fast chargers

Source: (CALeVIP, 2025; EPA, 2025; EVESCO, 2025)

2.3.3.2 Private EV charging

2.3.3.2.1 Home charging

Prospective EV owners on the island can charge at home using the standard 3-pin plugs or get a dedicated EV charger. Installing a home charger typically costs between €1,200 and €1,600 (SEAI, 2024a). To lower this cost, individuals can take advantage of the €300 grant offered by the SEAI to purchase and install EV home charging units.

2.3.3.2.2 PV-EV charging

As part of the ongoing efforts to integrate renewable energy technologies into the transportation on the island, PV-EV technology can be a potential opportunity. This involves using power generated from solar PV to charge EVs. The homeowner will have solar PV installed for use by the home. A home EV charger is connected to the electricity grid in the house through an exterior unit, which is typically mounted to the home's wall or even through a standard 3-pin plug. However, a key limitation is that EVs must be home during the day to charge their vehicles, which is impractical for those driving to work. A possible solution is to use backup batteries to store excess solar energy produced during the day and charge EVs when the owner returns home in the evening.

2.3.4 Transitioning minibuses to e-Buses

The 26 minibuses on the islands are owned by private individuals whose operations serve tourists (by providing bus tours) and residents (hop-on-hop-off service). Based on observations, the minibuses used on the island are the Mercedes-Benz Sprinter, Ford Transit and VW Transporter. Considering the brand's and model's existing popularity, a good potential EV alternative for these buses would be the Mercedes-Benz eSprinter (Mercedes-Benz, 2025) or the Leyland DAF Van LDV EV80 (PickAnEV, 2020). A breakdown of the features of both vehicles is summarized in the table below.

According to survey findings, minibus operators also park their vehicles at home and do not follow a strict schedule for closing from work. Instead, their closing times depend on how busy the day has been. Therefore, like private EV owners, they could use the standard 3-pin plug,

install dedicated wall boxes in their homes or charge at a public charging infrastructure installed at the pier.

Table 2.24. Comparison of electric van features

Data source: (Mercedes-Benz, 2025), (PickAnEV, 2020)

Feature	Mercedes-Benz eSprinter	LDV EV80
Battery Capacity	81 kWh or 113 kWh	56 kWh
Range	Approximately 241 km (81 kWh) and 332 km (113 kWh) on a full charge	Approximately 193 km on a full charge
Payload Capacity	Up to 1,190 kg with the larger battery option	Approximately 1,000 kg
AC Charging	AC charging time from 0% to 100%: • 12h 30 min with 7kW • 8h 30 min with 11kW • 4h 30 min with 22kW	AC charging time from 0% to 100% is approximately 8 hours.
DC Fast Charging	Standard DC fast charging at 50 kW: 10% to 80% in about 93 minutes; optional 115 kW DC fast charging: 10% to 80% in approximately 42 minutes	DC fast charging capability up to 30 kW; charging from 0% to 80% in approximately 90 minutes.



Figure 2.24. Charging for Mercedes-Benz eSprinter
Source: (ZapMap, 2020)



Figure 2.25. Charging for LDV EV80
Source: (Hubbard, 2019)

2.3.4.1 Public EV charging

Since there is no public charging infrastructure on the island, there is an opportunity to build one that will allow bus drivers to charge their buses. It is proposed that the minibuses be charged at the pier during peak hours, specifically while waiting for passengers to disembark from the ferry, optimizing downtime. Additionally, intermittent home charging after work hours could enhance their convenience and operational efficiency.

2.3.5 Methodology

2.3.5.1 *Estimation of electricity demand for electric vehicles.*

The average daily driving distance and consumption figures of the cars were required to estimate the electricity demand. The consumption values of private cars on the island were based on the 40kWh Nissan Leaf average consumption figures of 0.23 kWh/km (EV Database, 2015). This assumption was based on the results of this study on the island, which revealed the brand as the most popular. It also factored in the used condition of the cars on the islands. Additionally, from the study, most of the public minibuses on the island were Mercedes Benz Sprinters. Therefore, an assumption was made that in their transition journey from diesel to electric, they would consider purchasing an electric version of the similar brand, the 81 kWh Mercedes Benz eSprinter, whose consumption averaged 0.6 kWh/km (Danish Energy Agency, 2023)

The average annual mileage of vehicles in the Aran Islands is about 8,000 km (J. Rivas et al., 2018a) which translates to an average daily driving distance of 22 kilometres. This value was assumed for all other months of the year apart from summer months and an intermediate season just before and after summer, where the distance for public minibuses was 44 and 33 kilometres respectively to account for the increased tourism activity on the islands.

2.3.5.2 *Scenarios definition*

The current electric vehicle statistics on the islands were used to define the business-as-usual (BAU) scenario for private EVs. According to CFOAT, the island has 25 operational electric vehicles representing a penetration rate of approximately 6.5% when compared to the total number of vehicles on the islands including public minibuses.

The second scenario involved a realistic view that by 2030, the private EV penetration on the Aran Islands would reach 15%. Although the Irish government (Irish Department of Transport, 2023) targets 30% of its private car fleet to be electrified by 2030, the same could not be assumed for the islanders since they don't buy brand new cars thereby necessitating a pragmatic approach on this scenario.

Thirdly, to provide input for future planning of the islands' energy supply system, a 100% EV scenario was also developed based on the current total number of vehicles on the islands. This scenario assumed an exploratory approach, with owners of all the diesel cars on the islands gradually transitioning to electric vehicles. It also included modelling the Aran Islands public transport system where all the 26 minibuses on the islands were considered electric.

2.3.6 Resulting demands

2.3.6.1 *Load curves for electric vehicle charging*

To generate a representative load curve for private EV charging on the Aran Islands, an uncontrolled home charging behaviour was assumed. Interviews conducted during this study revealed that most of the private EV users on the island preferred charging their cars at home.

Since the islanders preferred charging at home, the charging distribution assumed a peak in the evenings after work. Considering not all cars would start charging at the same time, a staggered charging pattern with a 3.2 kW charger was assumed based on coincidence factors of uncontrolled home charging for Nordic countries (Liu et al., 2014). Peak time for the rest of the year was estimated to be at 6pm, an hour after working hours, while for the summer season, it was estimated to be at 8pm, taking into consideration the longer day times.

During the rest of the year, the peak electricity demand for private cars is approximately 182kW, 27kW, and 13kW for 100%, 15% and BAU electric vehicle scenarios respectively. The peak charging time occurs at around 6pm implying that most islanders likely plug in their cars almost immediately after getting back from work. There is a gradual decline in demand as time

progresses, which signifies that most of the cars that had been plugged in are fully charged. The minimum demand is observed between 8am and 9 am as the time coincides with the normal commuter hours on the islands.

The resultant load curves for private cars on typical days in summer and the rest of the year are as shown below.

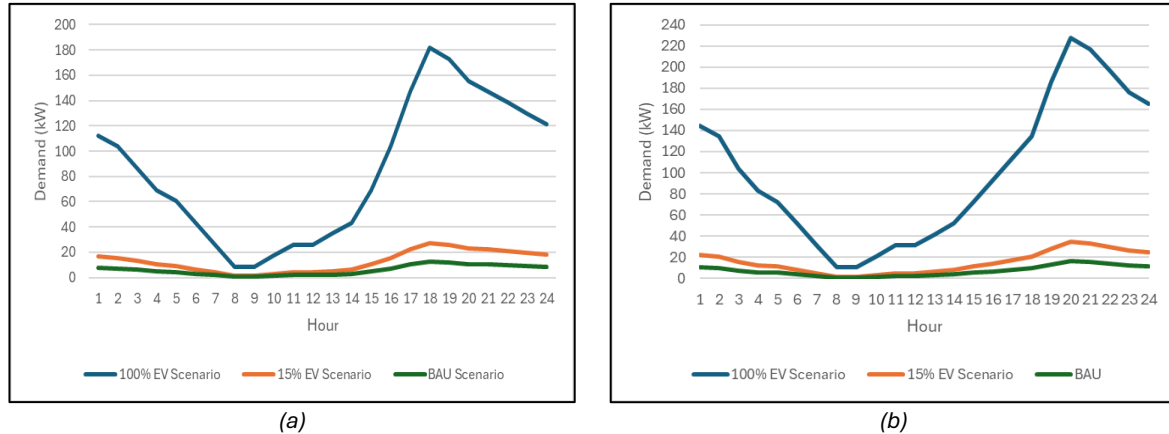


Figure 2.26. Daily load curve of electric cars during the rest of the year (a) and summer (b)

Similarly, the peak electricity demand for summer was approximately 228 kW, 34 kW and 16 kW for 100%, 15% and BAU electric vehicle scenarios respectively. The increase in energy demand during this season is associated with increased islander activities. It is expected that local people are likely to engage in other activities after work instead of going home immediately resulting in a shift in evening peak to 8 pm.

Consequently, the annual energy demand for 100%, 15% and BAU electric vehicle scenarios were estimated to be about 776 MWh, 116 MWh and 54 MWh respectively. An illustrative annual hourly profile for the 100% private electric vehicle scenario for the islands is shown in the figure below where the months of June, July and August have significantly higher energy demand as compared to other months of the year.

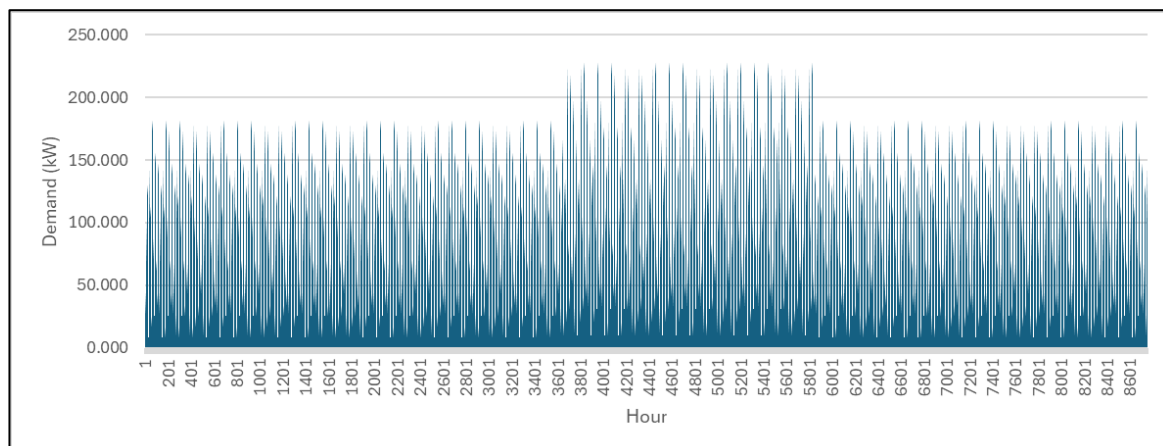


Figure 2.27. Annual load profile for 100% private electric vehicle scenario

A similar methodology for generating a load curve for the public minibuses was also adopted but with a bigger capacity home charger rated at 7.4 kW and a public charger rated at 22 kW. On the charging pattern, it was assumed that the minibuses charged during daytime at the main pier while waiting for passengers from the ferry and randomly at home after work. Three seasons of operation of the minibuses were considered based on the frequency of the ferry to the main island from Rossaveel. From the timetable, the minimum number of trips per day was two, three

and four for the off-peak, intermediate and peak seasons respectively. For this research, the peak season considered was during the months of June, July and August while the intermediate season was in April, May and September. All the remaining months of the year were considered off-peak season.

Figure 2.28 below shows typical daily load curves for the minibuses for the three seasons. During the off-peak season, two peak demands were observed at 10am and 8pm while three peaks at 10 am, 1 pm and 8 pm were observed during the intermediate season. Most of the charging was also observed to take place between 10 am and 1 pm and later at 9 pm during summer. These peaks during the day occurred a few minutes before ferry arrival which implied that bus drivers utilised the public charger at the main pier as they waited for the tourists. The evening peaks observed at 8 pm and 9 pm are because of home charging after work.

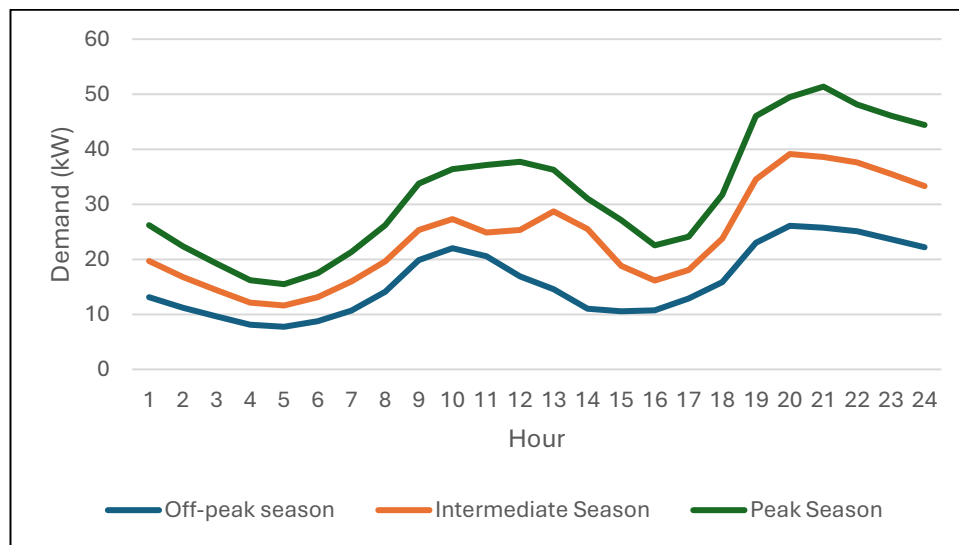


Figure 2.28. Typical daily load curve for minibuses for different seasons

The annual demand for the 100% public electric minibus scenario was thereafter estimated to be 175 MWh and is illustrated by the hourly profile below. The months of June, July and August recorded highest electricity demand followed by April, May and September while the remaining ones had the least electricity demand.

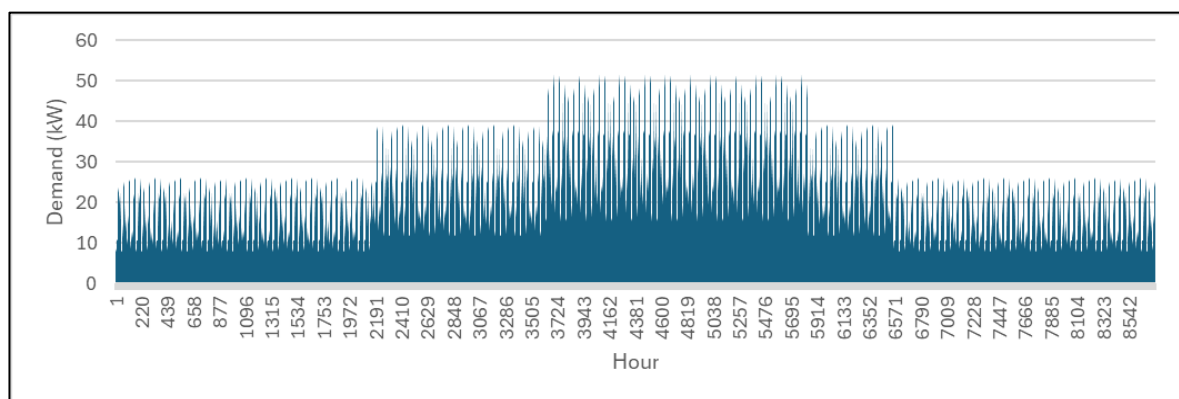


Figure 2.29. Annual load profile for 100% public electric minibuses scenario

2.3.7 Cost analysis

An analysis to evaluate and compare the costs and environmental impacts of diesel cars and EVs based on different factors was done, and Table 2.25 below outlines the key assumptions considered in evaluating these parameters.

Table 2.25. Assumed parameters to calculate cost-benefit parameters

Parameter	Assumption	Source
Average covered distance in km per day	22 km	(Energy Master Plan 2018 Árann and Inis Meáin, 2018)
Nissan Leaf energy consumption kWh/km	0.23 kWh/km	EV Database, 2015
Grid Emission factor consumed	0.255kg CO ₂ /kWh	Table 1.1
Diesel Emission factor	2.68 kgCO ₂ /l	Table 1.1
Diesel Costs	1.9 euro/l	Local fuel pump at the Island
Bus fuel consumption	15l/100km	(Technology Descriptions and Projections for Long-Term Energy System Planning. Commercial Freight-and Passenger Transport, 2023)

2.3.7.1 Purchase price

Currently, all EVs on the Aran Islands are pre-owned. To ensure a fair comparison, second-hand internal combustion engine vehicles were also considered in this analysis. From the interviews conducted, EVs still have higher upfront costs, making diesel second-hand cars the preferred choice for most islanders due to their lower initial purchase price.

2.3.7.2 Fuel costs and energy costs.

All vehicles on the islands collectively consume 226,167 litres of diesel (2300 MWh) annually (J. Rivas et al., 2018). To determine the fuel spent on the buses on the island, a single bus was estimated to consume 15l/100 km. During the tourist peak period that runs from June, July and August. In this season, 26 buses operate two routes covering 44 km daily, 13 buses operate during intermediate seasons (April, May, September) covering 33 km daily and only 5 buses operate during the rest of the off-peak months covering 22 km daily. According to one of the interviewees, most of the buses return to the mainland during winter times and only those owned by the locals remain operational during this season. Using Equation 2.8, the fuel spent on the buses during the three peak seasons was calculated to be 24,205 litres of diesel. The table below shows the amount of diesel spent on buses during different operating seasons.

$$(\text{Litres of fuel spent on Buses}) = (No) * (Do) * (Ao) * (Bo) \quad \text{Equation 2.8}$$

Where:

No is the number of buses available on the island, **Do** is the distance covered by the buses on a daily basis in Km, **Ao** is the number of days buses operate in one year and **Bo** is the fuel consumed by the bus per km.

Table 2.26. Diesel covered by buses in different seasons

Seasons	Operating Buses	Covered Distances(km)	Operating days	Diesel Consumed (Liters)
Peak	26	44	90	15,444
Intermediate	13	33	90	5,792
Off-peak	5	22	180	2,970
Total diesel consumed by buses				24,205

2.3.7.2.1 Fuel cost of private diesel cars

The annual fuel consumption of the 359 private cars on the island was considered to be 202,082 litres of the 226,167 litres of the total fuel consumption. The fuel cost of a single private car per year was calculated to be 1070 euro using the Equation 2.9 below.

$$\text{Fuel cost of a private car} = \frac{To}{Np} * Co \quad \text{Equation 2.9}$$

Where:

To is the total diesel consumed by all private cars, **Np** is the number of private cars on the island and **Co** is the unit price of one litre of diesel.

2.3.7.2.2 Electricity cost on EVs

To estimate the cost of electricity spent charging the EV annually, a Nissan Leaf SV with a 40 kWh battery estimated to consume 0.23 kwh/km was considered for the study. Using different charging rates as shown in Table 2.27 and the electricity costs annually spent when a Nissan Leaf SV is charged using Daytime standard rate and night time standard rate were calculated using Equation 2.10 as shown below.

$$\text{Cost of Electricity to charge an EV} = De * Cb * Ce \quad \text{Equation 2.10}$$

Where:

De is the distance covered by EV annually in Km, **Cb** is the energy consumed per kWh/km and **Ce** is the unit cost of electricity in kWh.

Table 2.27. Annual cost for charging an EV

Electricity standard rates	Rate (c/kWh)	Annual cost of charging EVs (euro)
Daytime standard rate	29.7	549
Night-time standard rate	14.9	275

The calculated results show that less energy costs are spent on EVs than on diesel cars.

2.3.7.3 Maintenance Costs

Typical diesel car servicing includes an oil change and replacement of the engine oil filter, engine air filter, and cabin filter. These service schedules, other than suspension and cooling system checks, do not apply to EVs thereby requiring less periodic maintenance.

From the interviews conducted with the locals, both diesel and EV owners average their annual maintenance costs to 200 euro and 170 euro respectively which is inclusive of the cargo boat's 80 euro charge to transport the cars from the island to Galway since the island has no mechanic

During the survey, it was noted that most outdoor EV home chargers periodically malfunctioned, which can be attributed to the adverse conditions on the island. This adds to the unplanned cost of replacement.

2.3.7.4 Environmental impact

The environmental impact of EVs and diesel cars was determined based on noise pollution and carbon emissions released annually by each vehicle. From the conducted interviews, EV owners were very satisfied with the rate of quietness of their cars while driving in comparison to diesel cars that make noise because of the sounds produced by their engines and exhaust systems while being driven.

2.3.7.4.1 Carbon emissions by diesel vehicles

Carbon emissions released annually by a single diesel car were calculated using Equation 2.11, where a private car on the island is estimated to annually consume 563 litres of diesel that emits 2.68 kg CO₂ per litre of diesel burnt (SEAI, 2024). The amount of carbon emission released annually by a single vehicle was calculated to be 1509 kgCO₂/ year using the below equation.

$$CO_2 \text{ emissions produced by a Diesel Vehicle} = Lo * Eo \quad \text{Equation 2.11}$$

Where:

Lo is litres of diesel consumed annually, and **Eo** is the emission factor for diesel in kgCO₂.

2.3.7.4.2 Carbon emissions by EVs

EVs do not emit CO₂ while they are being driven; their emission comes indirectly from the electricity used to charge them. Currently, the used grid is estimated to release 0.255 kgCO₂ per kWh of electricity consumed by EVs (SEAI, 2024). Considering a Nissan leaf SV 40 kWh, the carbon emission released annually were calculated to be 471 kgCO₂ using Equation 2.12 below

$$\text{Indirect emissions produced by an electric Vehicle} = De * Cb * Ee \quad \text{Equation 2.12}$$

Where:

De is the distance covered annually by the EVs in km, **Cb** is the energy consumed per kWh/km, and **Ee** is the grid emission factor for electricity consumption in kgCO₂/kWh consumed.

2.3.7.5 Reflection of government incentives in EV costs.

The Irish government has introduced several incentives to encourage the transition to EVs, including grants for purchasing new fully electric vehicles, home charging grants, lower motor tax rates, and toll incentives. Second-hand EV owners are only eligible to receive the €300 home charging grant, which supports the purchase and installation of a home EV charger (Tithe an Oireachtais Houses of the Oireachtas, 2022). On the other hand, second-hand diesel vehicle owners receive no incentives at all. Such incentives make electric Vehicles look attractive however more grants and incentives will need to be implemented to grow the second-hand market of Electric Vehicles since it's what is preferred by the locals due to the small distances covered daily at the island according to one of the interview respondents.

From the above parameters and interviews conducted, the estimated annual costs for using a 10-year-old second hand diesel vehicle and an EV, each covering an annual distance of 8030km at the island were analysed to highlight potential savings while using an EV as shown in the table below.

Table 2.28. Estimated annual costs for owning a diesel vehicle or an EV at the island

Parameters	Diesel Car costs	EV costs	Cost savings	Units	Source
Electricity cost/ Fuel cost	1,115	275	840	euro	Calculated
Annual Maintenance	200	170	30	euro	respondent
Insurance	400	309	91	euro	respondent
Road Tax	102	102	0	euro	respondent
Emissions per year	1,506	470	1,036	kg CO ₂	Calculated

2.3.8 Barriers to transition to eBuses

Feedback from minibus drivers and bus operators reveals that the demand for minibus services is unpredictable, even during the peak tourist season. One operator shared that in the summer there is stiff competition among operators since 26 buses are in operation. However, in winter, only 5 buses operate as the number of tourists drops significantly, yet the demand remains just as inconsistent. This level of unpredictability poses a considerable financial risk when considering significant investments in purchasing new vehicles. Additionally, since most minibuses remain unused for extended periods in the winter season, their lithium-ion batteries can degrade due to prolonged inactivity and exposure to cold temperatures, reducing overall battery lifespan and performance (Collins, 2021; Wang et al., 2022). Without regular use or optimized storage conditions, capacity loss and increased maintenance costs could make EV adoption even less attractive for bus operators working only during the summer.

2.3.8.1 Key challenges

2.3.8.1.1 Developing second-hand market

Most buses on the island are Mercedes-Benz Sprinters, and the transition to electric buses is being evaluated using their electric counterparts, along with the LDV EV80. However, the second-hand market for these electric minibus models is still developing, with limited listings on sales platforms (see Carzone, 2025; DoneDeal, 2025; Windsor, 2025). However, the transition is not impossible, as models like the Ford Transit 350 electric (see Ford, 2025), although smaller than the size of minibuses currently used on the islands, could be viable for transportation.

2.3.8.1.2 Financial barriers and incentives

The high upfront cost of electric buses is a major barrier for island operators, many of whom rely on their vehicles for income. The seasonal nature of tourism further complicates investment decisions, as fluctuating demand makes it difficult to justify the initial expense. Single-vehicle operators are particularly disadvantaged compared to larger transport companies, as they cannot achieve the same cost efficiencies when transitioning to EVs.

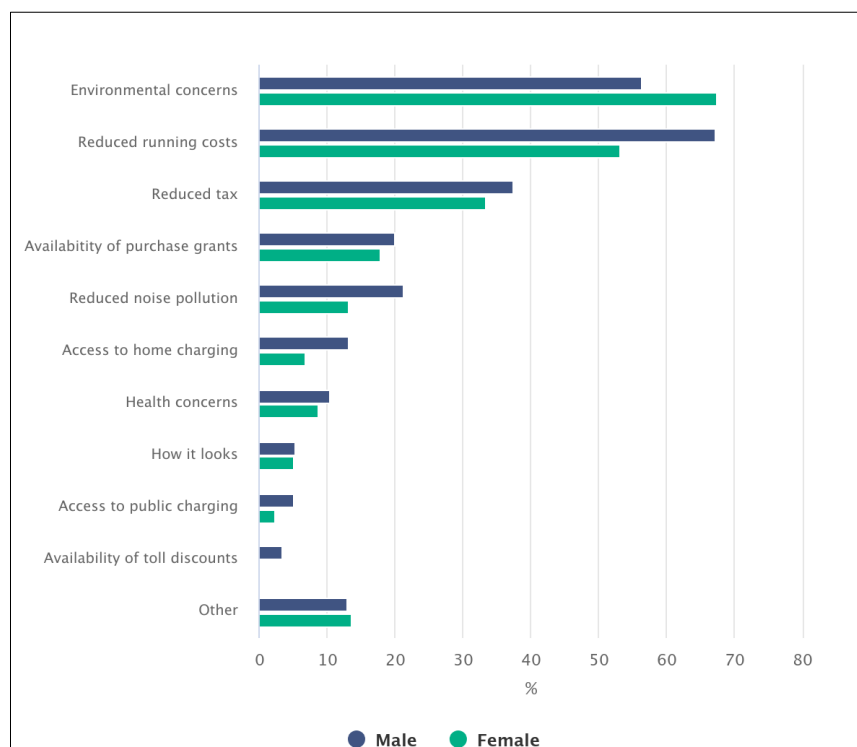


Figure 2.30. Factors influencing EV purchase in Ireland

Data source: (Ireland Central Statistics Office, 2021)

A 2021 survey by the Ireland Central Statistics Office examined the factors influencing EV purchases among current EV owners, with the top reasons being environmental benefits, lower running costs, and reduced tax, as shown in the figure below. However, this perspective differs from bus operators on the island, who have not yet transitioned to EVs. Conversations with local stakeholders indicate that financial viability, rather than environmental concerns or energy independence, is the primary consideration for these operators. This aligns with another key finding from the national survey, which reported that 63.1% of respondents who had not yet purchased an EV cited the high purchase price as the main barrier.

2.3.8.1.3 Infrastructure limitations

The absence of a public charging infrastructure makes adopting electric minibuses difficult. For bus operators, who typically park their vehicles at home, a successful shift to electric minibuses means having reliable and accessible charging options. Additionally, power outages caused by storms affecting certain regions of the mainland add to the uncertainty surrounding the reliability of operating EVs on the islands. Conversations with bus owners reveal that many are doubtful about switching to electric. Relying solely on EVs can be risky, especially since charging depends on electricity availability. For bus operators who rely on their vehicles for daily operations, the possibility of power outages hindering their ability to recharge is seen as a significant risk.

2.3.8.2 Recommendations

2.3.8.2.1 Financial support mechanisms

Policy reforms that allocate funds for purchasing used electric vehicles could help small operators transition to EVs. For example, Scotland's Energy Saving Trust offers interest-free loans for used EV purchases, repayable over six years (Energy Saving Trust, 2024). This model could be adapted for the island's needs. In addition, government-supported lease-to-own initiatives would allow operators to spread costs over a longer period, making financial management more feasible. Seasonal leasing contracts could reduce upfront investment by enabling operators to access EVs only during peak tourist months. Beyond individual financing solutions, collaboration among tourism boards, local businesses, and cooperative transport programs could provide shared funding opportunities, making electric vehicle adoption more accessible and sustainable for island transport operators. Additionally, surplus renewable energy could be offered at a reduced or zero cost to lower operational expenses, especially when curtailed during the summer.

2.3.8.2.2 Exploring a shared eBus model

Establish a cooperative or shared fleet model allowing various operators to access electric buses based on demand. This strategy would help reduce financial risks by spreading costs across multiple users while effectively addressing transportation requirements.

2.3.8.2.3 Infrastructure and charging solutions

Setting up a public charging station at the pier, managed by the island, could encourage more commercial operators to adopt electric vehicles. Another approach could involve utilizing the current home charger grant program to assist bus owners in installing EV chargers. This would help create the necessary charging infrastructure for those transitioning to electric minibuses.

2.4 Cooking demand

The residents of the Aran Islands utilise a variety of cooking fuels, including liquid petroleum gas (LPG; butane and propane), kerosene, and electricity, to meet their cooking needs. Tellarini & Gram-Hanssen (year) conducted an interview-based study to examine the reliance on multiple energy sources for heating and cooking on the islands. Their findings, combined with the data from this study, indicate a partial transition toward cooking electrification while a strong dependency remains on fossil fuel, as shown in Figure . According

to the figure, electric ovens (66%) and electric kettles (73%) are widely used; however, gas hobs (80%) and gas ovens (47%) remain the dominant cooking sources. Tellarini & Gram-Hanssen further explained that the continued reliance on gas kettles and kerosene stoves reflects residents' concerns over electricity supply reliability, leading them to maintain backup systems. This aligns with broader trends in island communities, where energy security concerns shape household energy choices, even amid decarbonisation efforts.

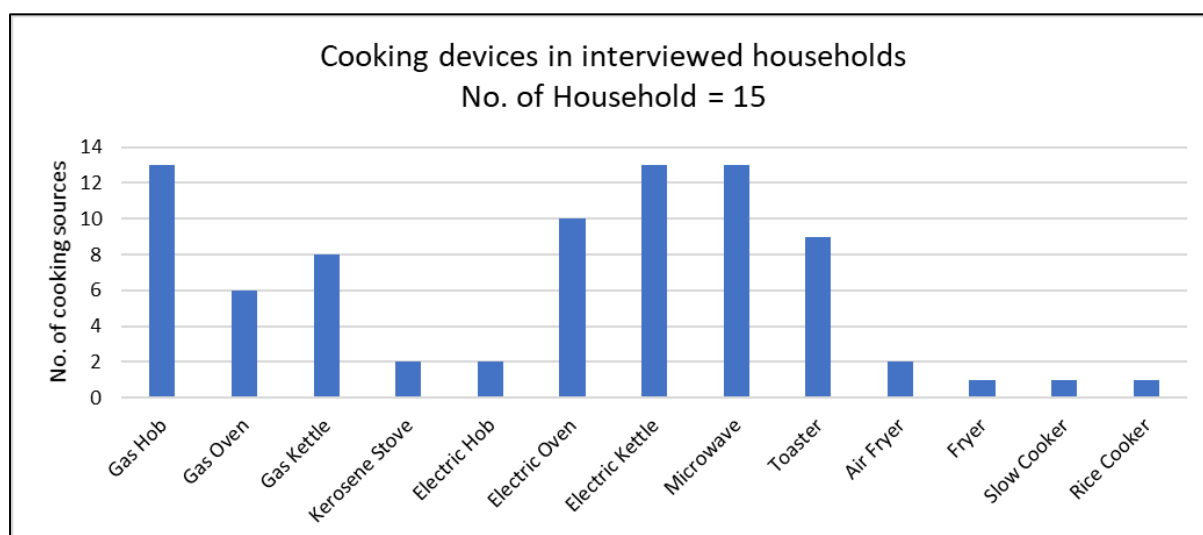


Figure 2.31. Cooking devices in the interviewed households (n=15)

Data source: (Tellarini & Gram-Hanssen, 2024)

To facilitate the island's transition toward cleaner cooking energy while respecting existing energy preferences, the introduction of dual-fuel (gas and electric) cookers may provide a viable intermediate solution. To support this decarbonisation effort, in this section, we aim to estimate the cooking electricity demand using data from the Aran Islands Energy Master Plan (2018), the Energy Audit on the Aran Islands (2015), and the 2022 Census from the Central Statistics Office (CSO), applying the following methodology.

2.4.1 Methodology

To estimate cooking energy demand, we assumed an average of 0.25 kg of LPG per permanently occupied household per day and 0.2 kg per holiday home. Based on observations and discussions with the community, we estimated seasonal occupancy rates for both permanent residences and holiday homes, accounting for fluctuations due to tourism and the significant number of residents who leave the islands during the off-peak season (as shown in Figure 2.32). Additionally, we considered that 30% of households (a total of 502) rely on electricity for cooking.

These assumptions resulted in a total LPG cooking energy demand of 471 MWh, representing approximately 5.1% of the islands' total thermal fuel imports. The equivalent cost of this amount of LPG is around 14,000 euro, considering 36 euro per 11.34 kg cylinder of butane. Furthermore, considering the 40% efficiency of gas hobs and the 90% efficiency of electric induction hobs, we estimated an electricity demand of 210 MWh.

To distribute this electricity demand across breakfast, lunch, dinner, and tea breaks, we divided the 24-hour period into seven segments, reflecting the demographic characteristics of the community (as detailed in Table 2.29). Each segment was further broken down into hourly allocations using estimated coincidence factors, ensuring a realistic load curve without sharp peaks or sudden ramps.

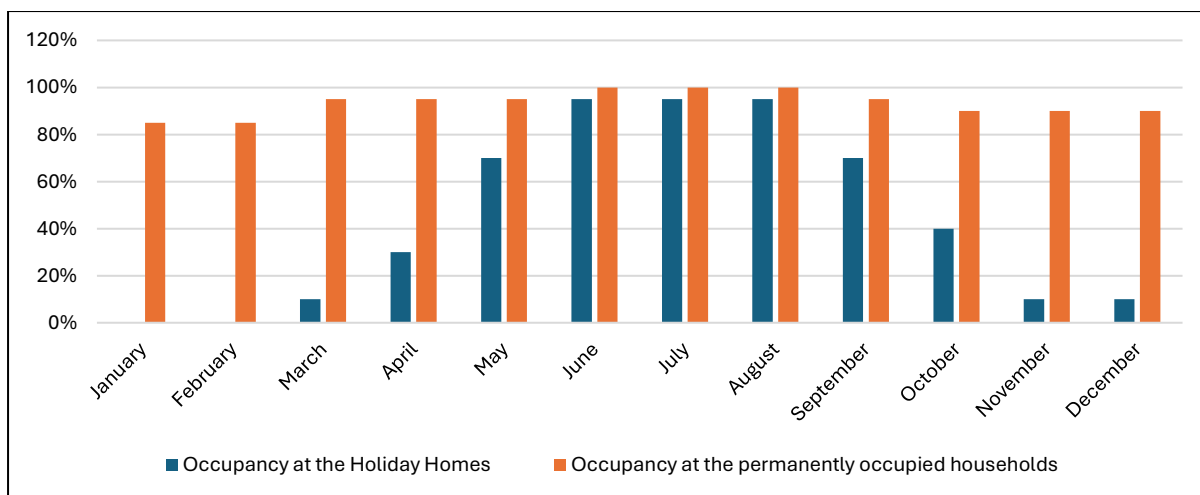


Figure 2.32. Estimated occupancy at the permanently occupied homes and holiday homes

Table 2.29. Distribution of daily cooking energy demand

Meal	Negligible cooking	Break-fast	Brunch and Tea	Lunch	Tea	Dinner	Late dinner
Time Segment	00:00 - 06:00	06:00 - 09:00	09:00 - 12:00	12:00 - 15:00	15:00 - 18:00	18:00 - 21:00	21:00 - 00:00
Share of daily cooking energy demand	0.2%	15.0%	10.0%	30.0%	5.0%	35.0%	4.8%

2.4.2 Resulting demands

Using the aforementioned methodology, we developed an electricity demand profile for electric cooking on the Aran Islands (as shown in Figure 2.33). The load curve exhibits three distinct peaks corresponding to breakfast, lunch, and dinner, with demand increasing progressively across these meals. Dinner represents the highest energy consumption period. The peak cooking load was identified as 120 kWh, while the minimum recorded demand was 0.01 kW, highlighting the variability in electricity usage throughout the day. To put into context, the 120 kW of peak power can host about 70 nos. of 18 cm electric cooking hobs or about 60 nos. of 2,000 W electric kettles simultaneously.

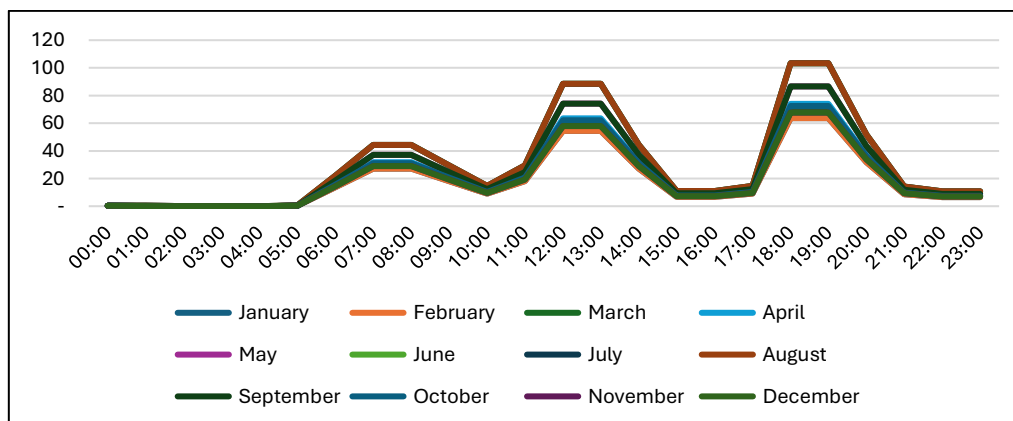


Figure 2.33. Monthly cooking demand profile for electricity-based cooking

2.4.3 Cost assumptions

The cost to replace traditional stoves with electrical stoves, including the cost of cables and necessary adjustments, was assumed to be 500 euro per household. Installing the electric stoves through a certified electrician can drive the cost up to 1,000 euro per household.

3 Renewable energy technologies assessment

This chapter provides a thorough evaluation of four different renewable energy resources and technologies—solar, wind, wave, and tidal—on the Aran islands. Through detailed analysis, the goal is to explore the potential for each technology's future application. We will pinpoint suitable locations for implementation and present essential technical and financial insights. This data will play a key role in shaping various energy scenarios and guiding the strategic development of sustainable energy solutions for the islands.

3.1 Solar energy

Solar energy stands as one of the most promising renewable energy sources, capable of making a significant contribution to meeting energy demands. According to the International Energy Agency (IEA), Solar PV is booming worldwide, breaking records in both emerging and advanced economies as its cost rapidly declines (IEA, 2025). This remarkable decline has positioned solar PV as one of the most cost-competitive electricity generation technologies in many parts of the world. In this section, we will assess the potential for both solar parks and rooftop solar installations on the Aran Islands. Additionally, we will identify suitable sites to maximize the effective use of solar energy in the region.

3.1.1 Solar Park potential Assessment

When assessing potential sites for solar PV power plants, it's essential to consider a range of factors, including economic, geographic, technical, social, and environmental aspects. For the Aran Islands, we used the Geographic Information Systems (GIS) software ArcGIS Pro combined with field research to evaluate and analyse suitable locations. First, key factors were identified and weighted to classify areas based on their suitability. Next, constraints were mapped to highlight unsuitable locations, which we'll explore both methods in detailed later. By overlaying the weighted factors and constraints, we generated a suitability map for the region. Finally, we excluded the protected areas such as Special Area of Conservation (SACs), Special Protection Area (SPAs) and Natural Heritage Area (NHAs), archaeological sites, buildings, and concluded suitable locations proximity with the powerline infrastructure for solar PV installations.

The following Figure 3.1 provides an overview of the approach used in this analysis.

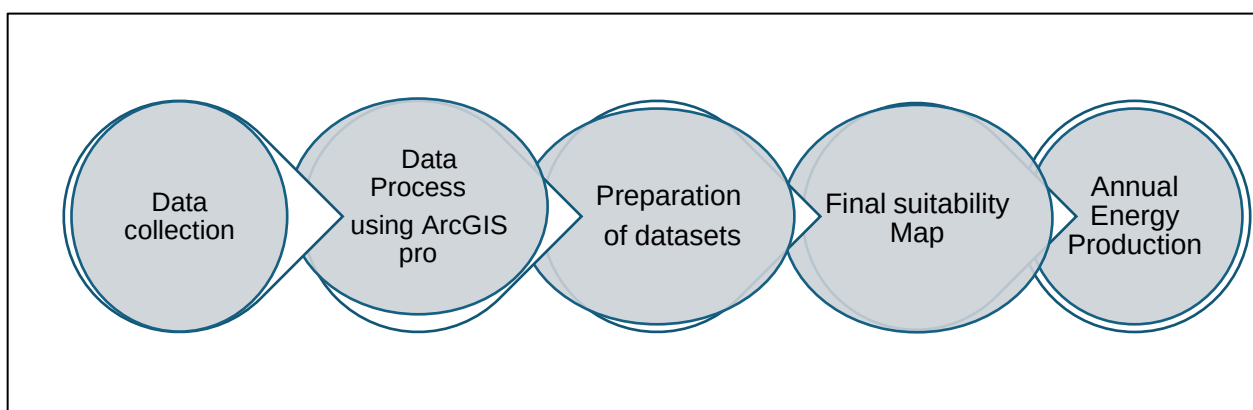


Figure 3.1. Solar PV area suitability mapping process

3.1.1.1 Data collection

The first step of the analysis focused on data collection. This involved gathering a wide range of information, such as satellite imagery, topographic maps and climatic data and used for further evaluation. The freely available datasets (Table) have been used in the study.

3.1.1.2 Data process using ArcGIS

When identifying the best locations for solar PV farms, studies emphasized the importance of considering multiple factors such as topography, socio-environmental conditions, and economic aspects. In this assessment we focus on three main criteria: climate, terrain, and location as depicted in Figure . These factors encompass details such as solar radiation, slope, aspect, land cover, distance from road networks, special protection area, special area of conservation, natural heritage area, and archaeological sites to ensure evaluating the suitability of solar PV systems. The land ownership, topographical visibility, distance from the powerlines were not considered in this study.

All dataset's extents are clipped to the study area and projected to project system (TM65_Irish_Grid). Slope in percentages and aspects are calculated from the Data Elevation Model (DEM) layer. DEM is a representation of the bare ground topographic surface of the earth excluding trees, buildings and any other surface objects (USGS, 2025).

3.1.1.3 Preparation of datasets

The preparation of the dataset for the suitability map involves organizing and processing spatial data layers—GHI, slope, aspect, and proximity to roads—to evaluate and identify optimal locations based on predefined criteria. Two methods are used in the analysis: the multi-criteria weighted average method and the exclusion method. The multi-criteria weighted average method is applied to combine the reclassified layers, reflecting their relative importance in the process. Each dataset is reclassified on a common scale, where 4 represents the most suitable, 3 represents moderately suitable, 2 represents less suitable, and 1 represents the least suitable, to ensure consistency and comparability. The exclusion method is a technique, where to eliminate areas that do not meet specific criteria. In this study, the constraint layers where 0 represents the presence of a constraint and 1 represents the absence of a constraint. This method is considered separately from the weighted overlay method and the constraint is mentioned under the dataset's preparation section. Table 3.1 summarizes the reclassification values of the datasets, and the corresponding figures can be found in the renewable energy technologies Appendices.

Table 3.1. Reclassification values for datasets

N°	Dataset	Suitability			
		4	3	2	1
1	GHI (kWh/m2)	994.5 - 998.5	990.2 - 994.6	985.4 - 990.2	978.9 - 985.4
2	Slope (%)	0.0 – 2.0	2.0 – 4.0	4.0 – 6.0	6.0 – 59.8
3	Aspect (Degree)	Flat & South	Southwest	Southeast	North, Northeast, East, West, Northwest & North
4	Proximity to Roads (km)	0.0 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 2.6

a) Preparation of global horizontal irradiation

Global Horizontal Irradiation (GHI) refers to the total solar radiation that reaches a horizontal surface on the ground. It is an important metric, and it includes both direct normal irradiation (DNI) and diffuse horizontal irradiation (DHI). In our study, GHI data is obtained from Global Solar Atlas (2024). Using ArcGIS software, this data is reclassified into four classes using natural breaks as shown in the Table 3.1 and Figure 6.7. Based on the Table 3.1, the poorest location is just 2% less sunny, so the GHI criterion is very little important comparing all locations in the islands.

b) Preparation of slope

Topographic conditions play a critical role in selecting suitable sites for solar photovoltaic (PV) installations, with slope being a key factor influencing solar radiation exposure. Steeper slopes can increase construction costs and environmental impact, making them less suitable for PV systems. In our study, we analysed the slopes on the Aran islands area using a Digital Elevation Model (DEM). The data was processed with ArcGIS terrain analysis tool. Table 3.1 provides a classification of the slopes along with their suitability ratings for solar PV installations. Slopes up to 2% are scored 4, slopes 2%-4% scored 3, 4%-6% scored 2, and slopes >6% are scored as 1 (Figure 6.8). Separately, the slopes >6% are considered as constraint in creation of Boolean constraints dataset.

c) Preparation of aspects

The aspect of an area refers to the direction in which a slope faces, which affects the amount of sunlight it receives. This is an important factor in assessing land suitability for applications such as solar PV installations. To optimize energy capture throughout the day, solar panels are most effective when oriented toward the south, southwest, or southeast (Noorollahi et al., 2016). In this study, data was derived from a Digital Elevation Model (DEM) and analysed using the terrain analysis tool in ArcGIS software. The Table 3.1 and Figure , outlines the classification of aspects and their associated suitability ratings.

Separately, all other directions except southeast, southwest and flat areas were considered as constraint in creating constraint dataset.

d) Preparation of proximity to roads

Building a solar farm near roads helps easier access to the site, reduce transportation costs for utilities and support teams. In the Aran islands, the Euclidean Distance tool was used to create a road proximity map. The maximum road distance for the study is 2,567 m and the distance is reclassified based on the criteria in Table 3.1, to further assess land suitability for solar farms. Areas within the distance range of 0 m – 1.0 km are scored 4, followed by 1.0 km – 1.5 km scored 3, the distance range between 1.5 km and 2.0 km are scored 2, and finally 2.0 km up to 2.6 km are scored 1. The Figure , shows the road proximity for the installation of solar PV farms. Separately, the distance greater than 1.0 km are considered constraint to create the constraint dataset.

e) Preparation of landcover

Land cover plays a significant role in selecting suitable sites for solar farms. According to (Noorollahi et al., 2016), the best land types for solar installations include barren land, rangelands, and shrubs, however, barren land on Aran islands are among the most valuable for the nature. While forests and agricultural areas are less favourable.

In this study, the land cover map was sourced from the European Space Agency (ESA, 2020) and has the types as shown in the Figure 6.11. It is reclassified based on the criteria listed in Table 3.2. The Figure 6.10 illustrates that grassland, cropland and bare vegetation are the most suitable for solar farm development. In contrast, tree cover, built-up, water bodies and herbaceous

wetland are considered unsuitable for solar PV installations. This data is considered constraint in creating constraint dataset.

Table 3.2. Reclassification values for landcover dataset

Land Cover Category	Classification
Tree cover	0
Grassland	1
Crop land	1
Built up	0
Bare/Sparse vegetation	1
Permanent waterbodies	0
Herbaceous wetland	0

f) Distance from buildings

We used OSM data to explore how close different types of buildings—like homes, businesses, schools, churches, and hotels—are to potential solar farm locations. As shown in the Figure 6.12, we excluded these buildings from the process and added a 50-meter buffer (consistent to report for solar farm – site screening in Aran islands) around them, for solar farm consideration. This step helps minimize the visual impact of the solar farms on the community and preserves the unique character of the islands.

g) Sites & Monuments Record (SMR) dataset

The SMR includes all known monuments and sites predating AD 1700, as well as selected post-1700 monuments, to safeguard archaeological heritage from development impacts (National Monuments Service, 2025). In our analysis, these SMR sites from Aran islands were excluded from solar farm installation. A 50-meter buffer (consistent to report for solar farm – site screening in Aran islands) was also applied around these areas to limit visual impact of solar parks from archaeological sites (Figure 6.14).

h) Special Protection Area, Special Area of Conservation & Natural Heritage Area dataset

The Aran Islands are recognized for their unique biodiversity and are protected under several conservation designations. Special Protection Areas (SPAs), Special Areas of Conservation (SPCs) and Natural Heritage Areas (NHAs) are established as protect areas of ecological, geological, or landscape significance (Figure 6.15). These designations collectively ensure the long-term conservation of the islands’ diverse ecosystems and cultural heritage (The Status of EU Protected Habitats and Species in Ireland, 2019).

In this case study, the areas dataset is gathered from Ireland’s department of housing, local government and heritage (National Parks and Wildlife Service, 2024), and checked it with the final suitability map. The areas which are overlayed are excluded to make sure the protected areas are not considered in the final suitability map.

3.1.1.4 Final suitability map for solar park

a) Multi-criteria weighted average method

This method ensures that more critical factors have a greater influence on the final suitability score. This process allows us to integrate multiple criteria into a single, comprehensive suitability map that considers all relevant factors for the optimal placement of solar PV installations.

Weighted Overlay tool was used to complete the suitability modelling. Slope, aspect, GHI, and distance from roads network were used as input layers. The input criteria were reclassified into

a common preference and the more favourable the criteria range, the higher the value. The criteria were weighted according to the Table 3.3 (Piirisaar, 2019). The Figure 6.16, represents the weighted overlay of factors in the Aran islands.

Table 3.3. Criteria weights

Factors	Weight (%)
Slope	13
Aspect	13
GHI	10
Roads Networks	64

b) Exclusion method

This approach focuses on identifying and removing regions that fail to meet the defined criteria, leaving only locations deemed entirely safe and appropriate for solar farm development. The constraint layers such as land cover, slope, aspects, distance from road networks are multiplied together and produced the final constraint layer (Figure 6.17).

The constraint layer and weighted factor layers were combined through multiplication to generate the final suitability map. To ensure compliance with conservation guidelines and protect sensitive areas, SPAs, SACs, NHAs, SMR zones, and the buildings layer were excluded from the final map, ensuring these protected zones were not considered for solar farm development. The Figure 3.2, depicts the final suitability map for solar farms in the Aran islands.

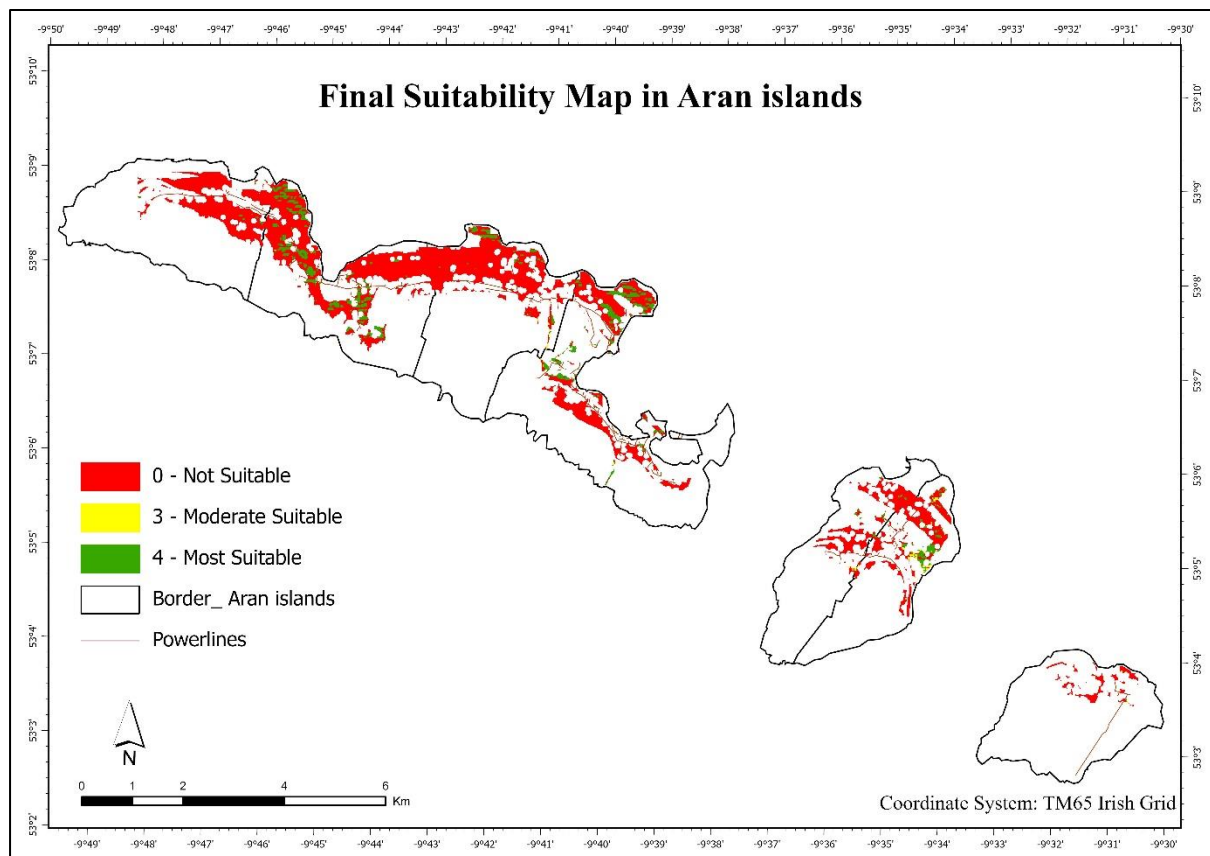


Figure 3.2. Final suitability map for Aran Islands

We applied zonal statistics to analyse the final suitability map and calculated the area for each suitability category. Based on the results, 7.35 km² of the area was identified as non-suitable for

solar farm development, 0.07 km² as moderately suitable, and 0.97 km² as the most suitable area. Protected zones (SPAs, SACs, NHAs, and SMR zones) were excluded from the analysis, along with buildings and a 50-meter buffer around them, which were treated as exclusion zones to minimize visual and social impacts.

Following the suitability assessment, we estimated the potential capacity for solar farms within the identified suitable areas. According to the technical reports, the land required for a 1 MWp solar PV plant varies: one source suggests 6 acres (Sunte, 2022b) while another indicates a minimum of 4.5 acres (Totally Dublin, 2023). To balance these estimates, we used a reference metric of 5 acres per 1 MWp of solar photovoltaic (PV) capacity to calculate the minimum and maximum potential.

By eliminating non-suitable and moderately suitable zones, we identified 12 potential sites (Figure 3.3) that could accommodate large scale solar PV power plants.

The distribution of these sites across the islands is summarized in the table below:

Table 3.4. Distribution of sites across the Aran Islands

Nº	Location	Place Name	Coordinate	Available Area (Acres)	Required Area (Acres/MWp)	Total Capacity (MWp)
1	Inishmore	Kilmurvey	9.7638513°W 53.1456975°N	5.7	5	1.1
2		Kilmurvey	9.7586931°W 53.1426678°N	8.3		1.7
3		Kilmurvey	9.7573917°W 53.1355065°N	7.0		1.4
4		Kilmurvey	9.7549434°W 53.1323333°N	6.2		1.2
5		Kilmurvey	9.7402311°W 53.1273524°N	8.0		1.6
6		Back Road	9.7342285°W 53.1220325°N	5.1		1.0
7		Oghil	9.7027043°W 53.1393955°N	5.2		1.0
8		Killeany	9.6626254°W 53.1297542°N	10.9		2.2
9		Killeany	9.6572276°W 53.1273592°N	5.7		1.1
10		Killeany	9.6661173°W 53.1264005°N	12.5		2.5
11		Back Road	9.6803983°W 53.1148095°N	6,1		1.2
12	Inshmean	Carrownlisheen	9.5702423°W 53.0858235°N	6.3		1.3
13	Total			87.1		17.4

The minimum capacity that can be installed is 1 MWp, and the maximum capacity is 2.5 MWp. The total capacity for the Aran Islands amounts to 17.4 MWp, considering 87.1 acres of land.

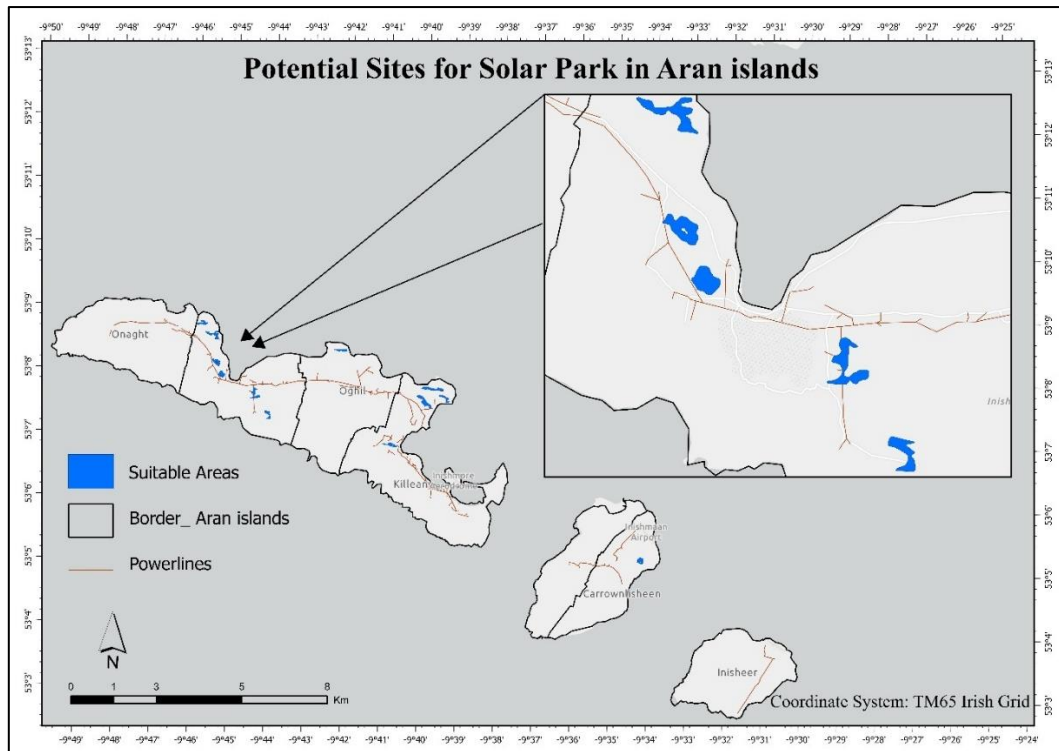


Figure 3.3. Potential sites for solar parks in the Aran Islands

3.1.1.5 Annual energy production for solar farm

After creating the suitability map, we estimated the annual energy production (AEP) for the identified areas. To calculate this, we used PVout values from the Global Solar Atlas and incorporated system design data from the Simulation Advisor Model (SAM) to determine land requirements for solar PV installations.

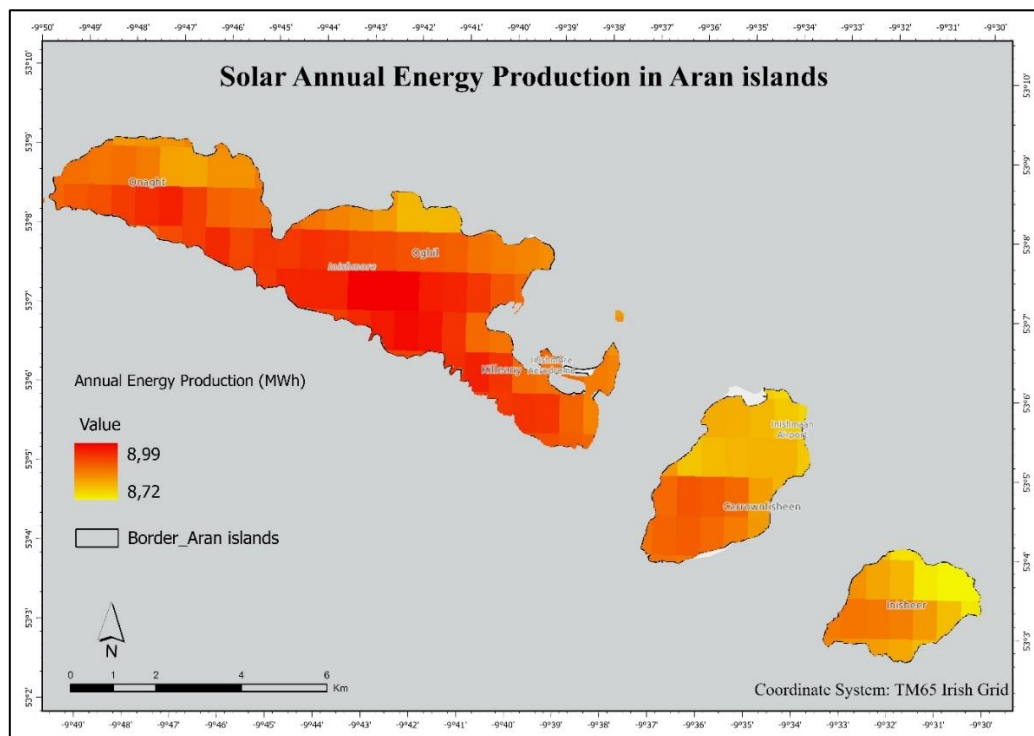


Figure 3.4. Annual energy production in the Aran islands

The results from the geospatial analysis show that the AEP values for the Aran Islands range between 8.72 and 8.99 MWh per year, as illustrated in Figure 3.4. The color-coded map highlights these variations, with red indicating the highest AEP and yellow representing the lowest. While the differences between values are slight, the high-potential areas (in red) are particularly promising for cost-effective and efficient solar energy projects.

3.1.2 Solar rooftop potential assessment

3.1.2.1 Methodology

Solar rooftop systems are one of the suitable options for households to generate electricity for either own use or grid export and can assist households to be more self-sufficient. In this section, we assess the potential of solar rooftops to support Aran island's electricity demand.

To conduct this assessment, we need to evaluate the number of residential buildings, their orientation, and the solar radiation potential on the islands. According to building footprint data from OSM, there are currently 816 residential buildings, including both occupied and abandoned, on the Aran Islands. These buildings vary in size, roofing material, and orientation. Using data from OSM, we filtered the buildings by type, focusing on houses and residential building footprints, as shown in Figure 6.18.

The orientation of houses is a critical factor in maximizing solar radiation absorption by solar panels. According to the building footprints data, approximately 38% of the houses face south, 22% face east to west, 25% face southwest to northeast, and the remaining 14% face southeast to northwest. While, based on the CSO data, there are 502 occupied houses on the islands. To estimate the orientation of these occupied houses, we applied the proportional distribution from the building footprints to the CSO data, the result is shown in Table 3.5.

Table 3.5. Number of buildings based on orientation from building footprints

N°	Orientation	Residential Buildings
1	South	312
2	East to West	180
3	Southwest	208
4	Southeast	116

Next, we estimated the solar energy generation for each building. Since it is not feasible due to time constraints to simulate a system design for every house, we modelled a 4 kWp system for each orientation using the System Advisor Model (SAM). The technical specifications of the selected system are outlined in Table 3.6.

Table 3.6. Technical specification of selected systems

Item	Specification
PV Module	10 x Jinko (400 Wp)
Inverter	1 x Solis (3.6 kWp)
MPPT	1 / 2
Tilt (Deg)	35
Orientation (Deg)	180 / 90 & 270 / 135 / 225

As shown in Table 3.6, the same PV module and inverter were used for all four systems. The number of MPPT inputs is two for the 90° and 270° orientations, while the others have only one MPPT. The tilt angle was set at 35°, determined through random sampling using a digital

protractor for the digital assessment of rooftop tilt angles. Four distinct orientation angles were included to accommodate the varying orientations of the houses. After simulating each system, one of the key outputs was the hourly solar generation data, as illustrated in Figure 3.5 for the south-facing system (data for other orientations can be found in the renewable energy technologies assessment appendices 6.2, Figure 6.19, Figure 6.20, Figure 6.21).

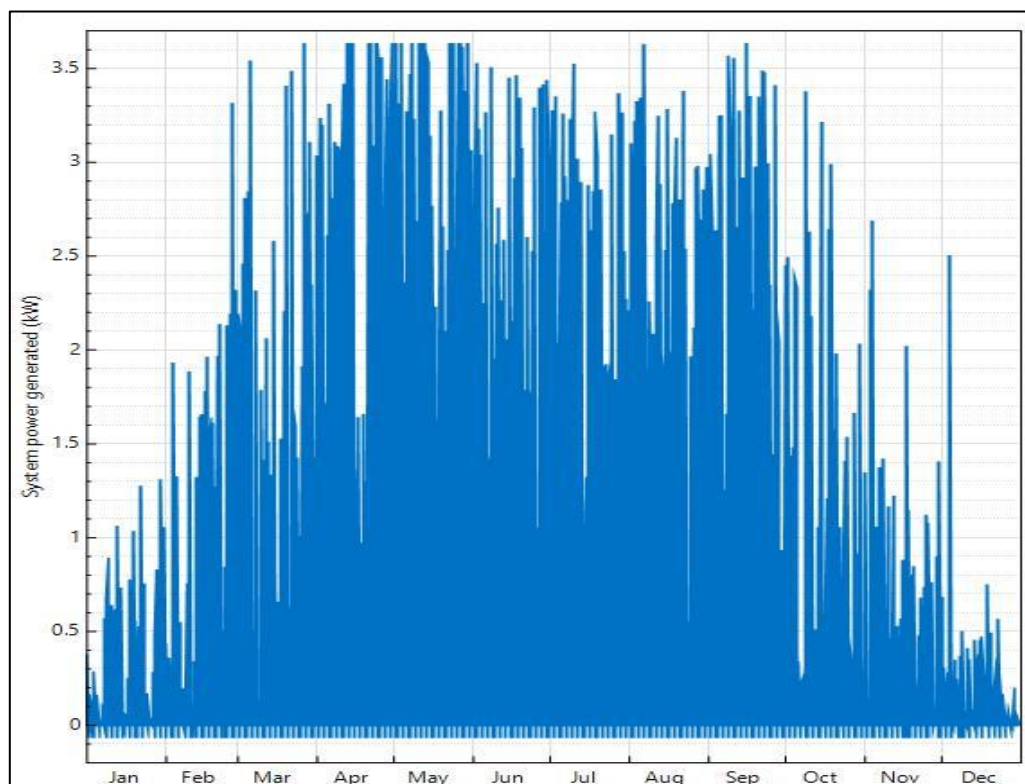


Figure 3.5. Time series of hourly data for south-facing system

This hourly data provides insights into the energy generation potential for each orientation.

3.1.2.2 Resulting potential

To estimate the total solar energy generation potential for the Aran Islands, we multiplied the hourly generation data by the number of occupied houses for each orientation. The results are summarized in Table 3.7.

Table 3.7. Total theoretical capacity of solar rooftop

N°	Orientation	Occupied House (Nos)	Annual Generation (MWh)	Total Generation (MWh)	Total Capacity (MWp)
1	South	192	3.64	698.88	0.71
2	East to West	111	3.01	334.11	0.34
3	Southwest	128	3.69	472.32	0.48
4	Southeast	71	3.29	233.59	0.24
Total Theoretical Potential					1.76

Assuming a 4 kWp solar installation, which requires approximately 20.2 m² of rooftop space, the theoretical total potential of rooftop solar system for the Aran Islands is 1.76 MWp. The potential from the solar rooftop capacity was then integrated into the energy system model to support the island's journey toward self-sufficiency and energy transition.

3.2 Wind

The Aran Islands can advance towards a sustainable energy future by harnessing wind power as a key renewable resource because wind energy stands out as a promising resource, not only due to its potential to meet the island's energy demand but also it aligns with the heating demand in winter season. For which a detailed evaluation of wind resource is carried out using a systematic approach.

3.2.1 Methodology

This section aims to assess the Aran Islands wind energy potential by creating a wind suitability map and calculating the Annual Energy Production. A systematic approach is adopted and for evaluating the Suitable areas for Wind turbine(s) installation, ArcGIS Pro is used and for LCOE and energy calculations WindPro is used. The methodology adopted is in Figure 3.6.

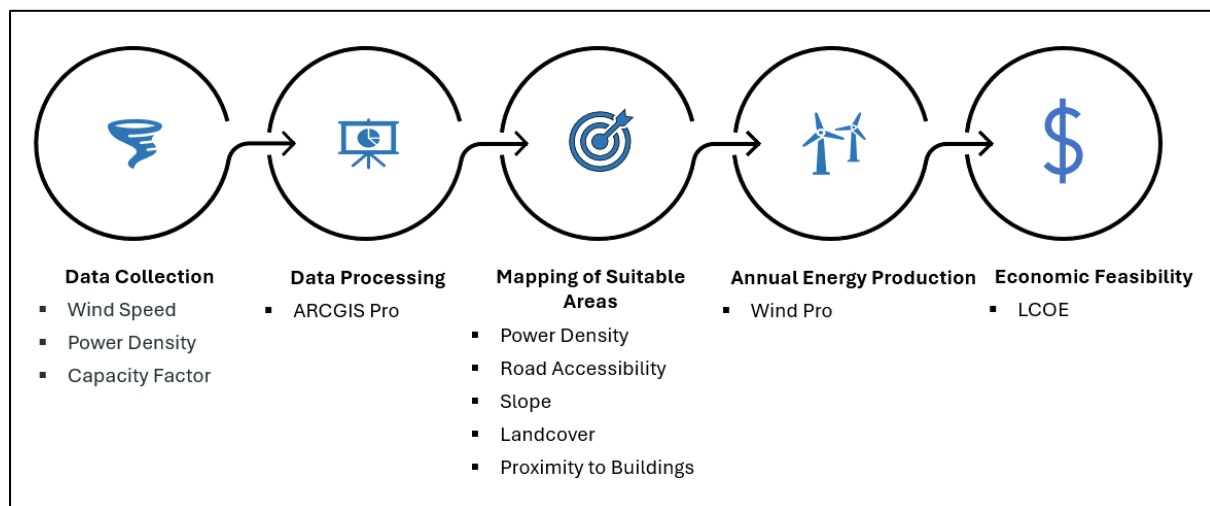


Figure 3.6. Methodology for wind resource assessment

3.2.1.1 Study area

Based on information provided by CFOAT regarding Natura 2000 guidelines (Department of Culture, 2019), the areas of conservation, protection, and heritage were excluded from the study area map (to preserve the islands' landscape significance) and remaining areas are assessed to identify the suitable locations for wind turbines installation. The green coloured area in the Figure 3.7 is the area of study taken into consideration for this project.

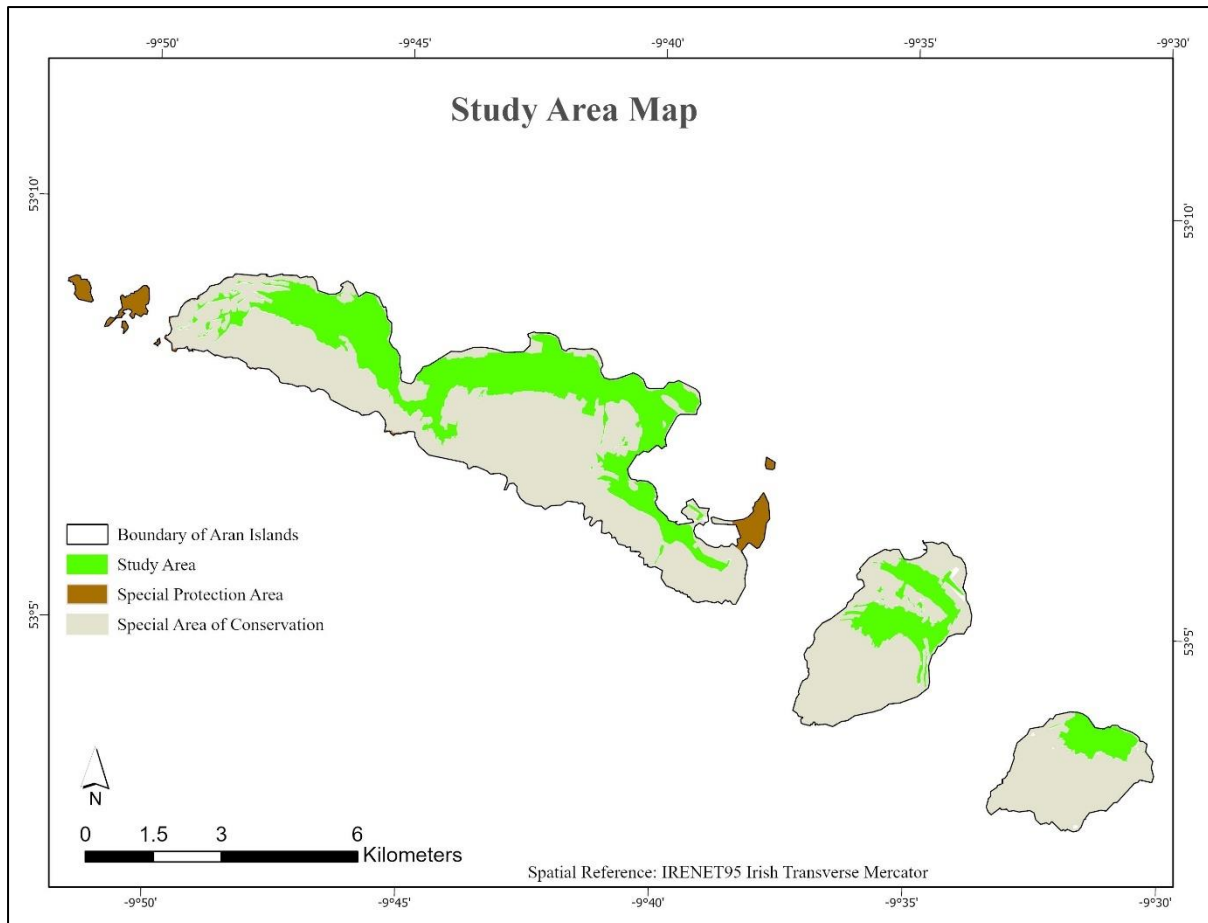


Figure 3.7. Study area map

3.2.1.2 Mapping suitable locations for wind turbines installation

Wind Speed, environmental factors (including Noise, shadow and visual impact), economic factors (Levelized cost of Energy) are all crucial in determining the suitability of locations for Wind turbines installation and each of these factors are to be carefully evaluated.

Multi-criteria analysis was applied in this project to determine the suitable site locations for wind turbines installation in the Aran Islands. The parameters used to determine suitability in this study are the mean wind power density, slope, land cover, roads and buildings. Input data was accessed and analysed from different sources and for all data files, it was intended to use the best spatial resolution. Details of the Input data are in Table 6.2. The data was projected to IREN95 Irish Transverse Mercator coordinate system and the suitability map was created using ArcGIS Pro. Moreover, the scoring system is based on a scale from 1 to 5, where 5 represents the highest level of suitability, and 1 indicates that the option is entirely unsuitable, with no degree of suitability whatsoever (except for wind power density where the range of value is considered as least suitable).

3.2.1.2.1 Wind power density

Wind power density is a measure of the energy potential of the wind at a specific location. In the Aran Islands, the power density in our study area ranges from 899 to 1,349 W/m². For choosing the ranges, histogram was used to show the distribution of values. The suitability classification and ranges used are in Table 3.8.

The areas of highest suitability are delineated and coloured green and these are largely confined to the mid-regions of the islands and particularly centred around the islands of Inis Inishmore

and Inishmaan, with no high-suitability regions on Inisheer. The resulting suitability map is in Figure 6.22.

3.2.1.2.2 Proximity to road network

Wind farms must not be too far away from the main roads, so that logistics for construction and maintenance work will be easier (Michel, 2024). In the context of the Aran Islands, the road network is not suitable for transporting heavy equipment. Therefore, helicopter might be required to lift large and heavy components such as turbine blades onto the installation location while light weight equipment can be moved using light transport vehicles. Moreover, for transporting heavy turbine equipment to the Aran Islands a specialized vessel like jack up vessel would be required. The suitability map is in Figure 6.23 in the appendices in which the unique distances excluded were within 150 meters of the road network due to safety concerns, based on the SEAI planning process which states that safe distance from roadways should be equal to the height of the turbine to the tip plus 10% (SEAI, 2024b) and the Table 3.8 shows the classification.

The distance to the roads is assessed using the Euclidean Distance tool, which measures the straight-line distance from each cell in a raster to the neighbouring roads. This process generates a distance raster, a direction raster, providing a comprehensive view of the spatial relationships to roads (ESRI, n.d.).

3.2.1.2.3 Proximity to settlements/buildings

Environmental impacts like noise, shadow flicker and visual impact (detailed analysis done in WindPro and is in the resulting potential section), arise due to the closeness of wind farm sites to habitation (Wiser, 2014). SEAI Planning process states that to keep optimal performance in consideration, a distance of not less than two rotor blades from adjoining property boundaries will be acceptable (SEAI, 2024b). However, we don't have dataset detailing these property boundaries. The purpose of the project is to provide settlements with energy to be produced from the wind turbine, therefore, for this reason areas with distance greater than 301 m were considered as suitable keeping in view of the criteria explained earlier. The classification of suitability score is in Table 3.8 and the resulting suitability map is in Figure 6.24 in the Appendices.

3.2.1.2.4 Land cover

The land cover is critical in order to evaluate the suitable locations for wind turbine installation as it helps avoid regulatory constraints, mitigate environmental impact, and maintain optimal turbine performance (Abdullah, 2024). In relation to land type, bare ground is the most suitable, followed by grassland, rangeland and agriculture land, while water, built area are deemed as not suitable (Azizi, 2014). The classification of suitability score is in Table 3.8 and the resulting suitability map is in Figure 6.25 in the Appendices.

3.2.1.2.5 Slope

The degree of slope of the terrain is used to classify the degree of feasibility in a suitability classification for the placement of wind turbines. Wind turbines are preferably constructed on flat terrains. A holistic approach for wind resource development considers sites with moderate horizontal slopes to maximize energy generation efficiency (Zalhaf, 2021). Using slope data as input and then using Reclassify which gives us the map according to the defined categories or classes based on suitability criteria, such as those for wind turbine placement. The classification of suitability score is in Table 3.8 and the resulting suitability map is in Figure 6.26 in the Appendices.

Table 3.8. Suitability classification

No.	Dataset	Suitability Score				
		Most Suitable	Suitable	Moderately Suitable	Least Suitable	Not Suitable
		5	4	3	2	1
1	Power Density (W/ m ²)	1100.1 - 1349	1050.1 - 1100	1000.1 – 1050	950.1 – 1000	899 - 950
2	Proximity to Roads (m)	151 – 300	301 – 500	501– 1000	> 1000	0 – 150
3	Proximity to Buildings (m)	501 – 600	301 – 500	201 – 300	101 – 200	101 – 200
4	Landcover	Bare Ground	Rangeland	Agriculture Land	-	Water, Built Area
5	Slope (degree)	0 – 3	3.1 – 7	7.1 – 10	10.1 – 15	> 15.1

3.2.1.3 Selection of the wind turbine

The annual average wind speed at 80 m was analysed based on the average of five years data from 2019 to 2023. This is necessary to analyse the wind speeds and eventually contributes to the selection of Wind turbines in terms of Wind Class. The annual hourly wind speed is in Figure 6.27 in the appendices.

Based on the wind speed data it was evaluated that the annual average wind speed is around 9.5 m/s. And it lies in the category of IEC Wind Class – I which is 10m/s (High wind). IEC Wind classes are defined in Table 6.3. in the appendices.

Moreover, the capacity factors for different wind classes were examined and for Class I the capacity factor is 53%. The capacity factors are described in Figure 6.28 in the appendices.

Furthermore, wind turbines below the capacity of 2 MW were also searched to cater for Aran Islands grid capacity constraints. Multiple manufacturers were checked for availability of wind turbines below 2 MW capacity including Vestas, Nordex, GE, Siemens Gamesa, but due to economies of scale, market demand of large wind turbines being more cost effective, manufacturers have moved from less than 2 MW models (Gary, 2023). Due to which Enercon E-82 with a capacity of 2,350 kW rated power and a hub height of 78m is chosen to characterize the electricity production from Wind energy. The technical data of Enercon E-82 EP2 E4 is in Table 6.4. in the appendices.

Moreover, in context of Project Management, Enercon has the presence in Ireland with Office in Dublin and the installed capacity of nearly 1.4 GW (Enercon, n.d.-b).

3.2.2 Resulting potential

3.2.2.1 Wind farm suitability map

The identification of suitable areas for Wind turbine installation involved the process of creating the model builder in ArcGIS Pro. Using the Reclassification tool, each layer was standardized by assigning values into classes of suitability. These layers were reclassified before using raster calculator and then the weighted according to their significance to suitability in the analysis.

The assigned weights of factors contributing to wind energy suitability is in Table 3.9, where Power Density weighs 30% and Slope weighs 20% highlighting the importance of both efficiency and constructability factors. Land cover each occupies 20%, denoting importance regarding environmental aspects. Other factors like Proximity to Roads and Proximity to Settlements are

weighed 15% each, enabling accessibility, while minimizing impacts to nearby communities (Yang et al., 2022).

Table 3.9. Weightage of factors for wind suitability map

Factors	Weight (%)
Power Density	30
Slope	20
Landcover	20
Proximity to Roads	15
Proximity to Settlements	15

The final wind suitability map categorizes the Aran Islands into five suitability classes: not suitable, least suitable, moderately suitable, suitable, and most suitable, as detailed in the Table 3.10. The most suitable areas for locating wind farms cover 2.47 km², representing approximately 17.33% of the total area. Moderately suitable areas account for the largest share at 27.21% (3.88 km²), followed by suitable areas with 32.90% (4.69 km²). The least suitable and not suitable areas make up 15.19% (2.16 km²) and 7.37% (1.05 km²) of the total, respectively. The selection of wind turbine locations is guided by the suitability map, ensuring areas with optimal conditions.

Two of the suitable locations were located at Inishmore and one was on Inishmaan. The resulting suitability map is in Figure 3.8. The coordinates of the suitable locations of wind turbines were then analysed in WindPro to find out the details regarding annual generation, environmental impacts, and economic factors.

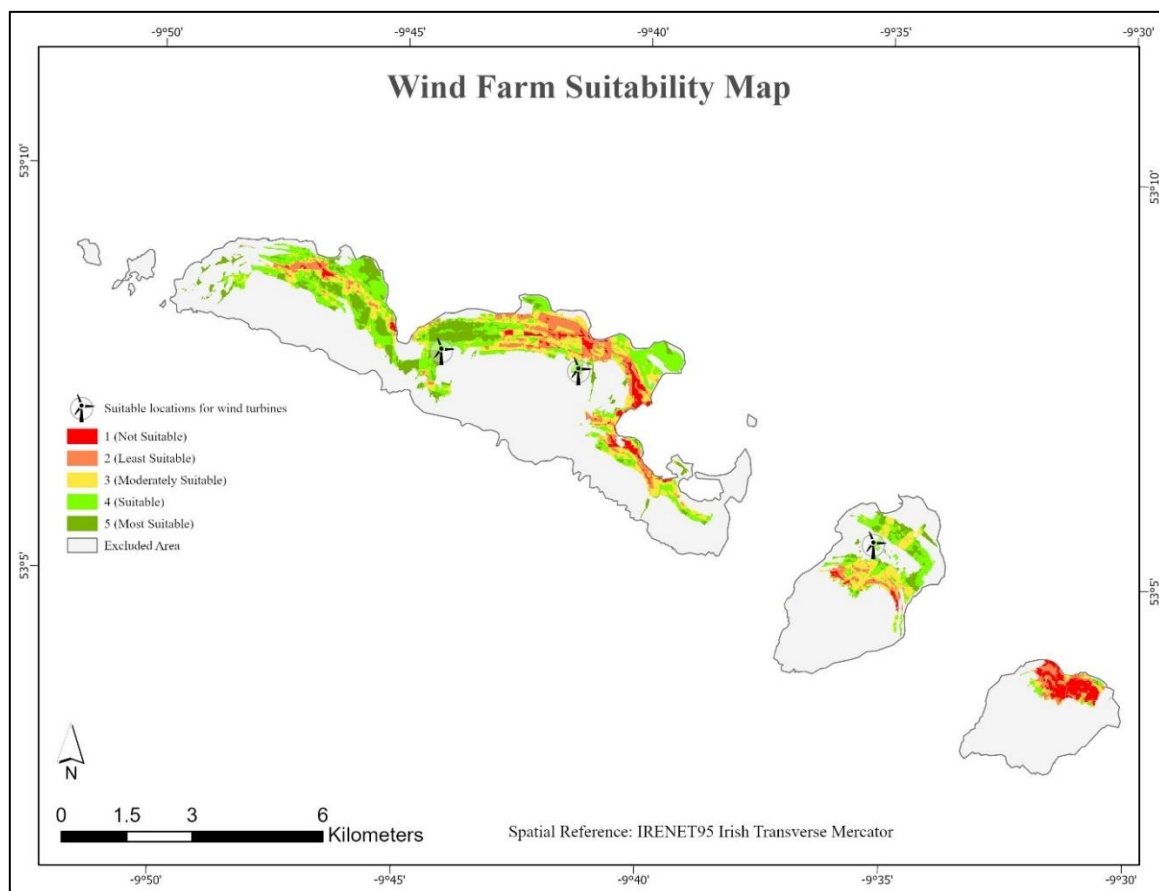


Figure 3.8. Map of suitable areas for wind turbines

Table 3.10. Area coverage for wind farm suitability map

Score	Suitability Class	Area km ²	% Area
1	Not suitable	1.052	7.37
2	least suitable	2.168	15.19
3	moderately suitable	3.884	27.21
4	Suitable	4.697	32.90
5	Most suitable	2.474	17.33
Total		14.275	100

3.2.2.2 Energy yield at a suitable location on Inishmaan

For the location 1 near to Cnriotáil at Inishmaan, no local data was available so three long term meteorological data were compared: MERRA-2 [50 m], ERA5 (T) Rectangular Grid [100 m] and ERA5 Gaussian Grid [100 m]. These sources were selected because of their proximity to the area of interest. But based on the distance of ERA5, it was discarded because of being distant as compared to the other two.

ERA5 (T) was selected in comparison to the results of MERRA-2 and because ERA5 (T) results are at 100-meter height and was closest to the height of the selected wind turbine 78 meters, whereas MERRA-2 was recording values at 50 meters height. The results of energy yield calculation in WindPro are in Table 3.11.

Table 3.11. Yield at location 1 (Inishmaan)

Result [MWh/y]	Result after losses (10%) [MWh/y]	Capacity Factor [%]	Full load hours [hours/year]	Mean Wind Speed @hub height
9,513	8,562	41.6	3,643	8.7

The detailed results are in Figure 6.29 in the appendices.

3.2.2.2.1 Shadow flicker effect evaluation

Shadow flicker in wind projects refers to the flickering effect caused when rotating wind turbine blades periodically block sunlight, casting moving shadows over areas such as residences. This effect can be an annoyance or even health concern for nearby residents. Based on (Malachy Walsh and Partners, 2020), shadow flicker should not exceed 30 hours per year or 30 minutes on any given day. These limits are designed to minimize the disturbance to individuals living near wind turbines (Lampeter, 2011).

Therefore, the calculated times are "worst case" given by the assumptions that: the sun is shining all day, from sunrise to sunset, The rotor plane is always perpendicular to the line from the WTG to the sun & the WTG is always operating. The consideration should also be given to nautical, astronomical twilights as well so the worst-case assumption of the sun shining all day is a rarity (Galtech Energy Services, n.d.). Moreover, the resulting map from WindPro was analysed and there were not any houses within the range 30 hours per year and all are located outside the degree shaded zone. The flicker result is in Figure 6.34 in the appendices.

3.2.2.2.2 Noise evaluation

Wind turbines generate mechanical noises, caused by a turbine's internal controls (i.e. pitch, yaw system etc.), and aerodynamic noise, caused by the blades passing through the air. Most of

the sound from wind turbines comes from the aerodynamic sound produced by the blades moving through the air (National Aerospace Laboratory NLR, 2011).

According to World Health Organization, the maximum allowable noise levels in residential areas are 45 dB during the day and 40 dB at night (Schwela, 2001). To simulate noise impact, the Noise Calculation Model ISO 9613-2 General was employed in Windpro. At the closest WTG site, located 302 meters from the noise-sensitive area, the sound level from the wind park was measured at 44 dB (somewhat like refrigerator humming noise), which is within the acceptable limit during the day as per guidelines. The noise map is in Figure 6.35 in the appendices.

3.2.2.2.3 WTG visibility evaluation

For this purpose, Zones of Visual Influence (ZVI) tool is used. It calculates the visibility of Wind turbine from any point in the landscape. As per the result the WTG is visible on the island but as per the CFOAT information and interaction with the some of the local community on the Islands during the surveys, those community members told us that they have no objection for the Wind turbines. Visibility evaluation result is in Figure 6.36 in the appendices.

3.2.2.3 Energy yield on suitable location at Inishmore

For the location 2 near to Dun Eochla at Inishmore, ERA5 (T) was selected amongst the results from MERRA-2 and ERA5 (T) because it is showing higher wind data and also it is at 100 m height which is close to the hub height of the wind turbine. The results of energy yield calculation in WindPro are in Table 3.12, moreover The detailed results are in Figure 6.33 in the appendices.

Table 3.12. Yield at location 2 (Inishmore)

Result [MWh/y]	Result after losses (10%) [MWh/y]	Capacity Factor [%]	Full load hours [hours/year]	Mean Wind Speed @hub height
9,570	8,613	41.8	3,665	8.8

3.2.2.3.1 Flicker effect evaluation

The resulting map was analysed and there were only two houses within the range of 30 to 100 hours per year and apart from that all are located outside the red shaded zone, furthermore, these two house have the value of 50 hours and 70 hours respectively, but here the consideration should also be given to Nautical, Astronomical twilights as well so the worst case assumption of the sun shining all day is a rarity. The flicker map is in Figure 6.30 in the appendices.

3.2.2.3.2 Noise evaluation

To simulate noise impact, the Noise Calculation Model ISO 9613-2 was employed in Windpro. At the closest WTG site, the sound level from the wind turbine was measured, which is acceptable as it not falling in the red-coloured area where the noise level is between 45 to 50 dB(A). The noise map is in Figure 6.31 in the appendices.

3.2.2.3.3 WTG visibility evaluation

As per the result the WTG is visible on the island but as per the interaction with the local community on the Island during the surveys, community has no objection for the Wind turbines. Visibility evaluation result is in Figure 6.32 in the appendices.

Location 3 at Inishmore was also analysed in Windpro, and it was concluded that the yield and capacity was comparable to other two locations but based on the environmental impacts in terms of flicker and noise, it is deemed as not suitable to install wind turbine at that location. Comparison of three locations is in Table 6.5. in Appendices.

3.3 Wave

In order to achieve a sustainable energy system for Aran Islands, wave energy, among other renewable energy potentials, is an opportunity to meet the energy demand and achieve energy security for the island. For this purpose, examining the resource potential of wave energy is very important. The resource assessment will follow the stated steps.

3.3.1 Methodology

During the resource assessment and finding possible sites for wave energy deployment, this study used a web-based GIS tool named Coastal Wave Atlas (CWA), developed under the Selkie Project. It is a cross-border project aiming to boost marine energy in Wales and Ireland by creating multi-use technology, engineering, and operation tools, templates, standards, and models for use across this growing sector. The Selkie methodology applies key site selection criteria of the site selection model, namely energy resource, depth range, seabed, subsea line/cable routes, and marine traffic, to identify potential sites (HORGAN, 2020). This study uses these selection criteria to identify sites around Aran Island for wave energy converter deployment.

3.3.1.1 Site selection & identification

For site selection and deployment of wave energy converters (WECs), the study uses the constraints presented in the Table 3.13.

Table 3.13. Wave site selection & identification criteria

Data source: (O'Connell et al., 2023)

All/Generic WEC		
Criteria	Measure	Value
Resource	Theoretical annual average resource (kW/m)	>15
Depth Range	Metres (m)	10–300
Seabed character	Folk 7 classification	Sandy Mud, Muddy Sand, Sand, Coarse Substrate, Coarse Substrate, Mixed Sediment
Accessibility	Annual frequency of $H_s < 1.5$ m and wind speed < 20 m/s (%)	>20%
Fishing	AIS density—hours/km ² /month	Busiest 20% (>17,396)
Protected areas	SACs, SPAs, MPAs and MCZs	Exclude all
Cable access	Excavation classification	Excavatable

3.3.1.2 Theoretical resource potential

The highest theoretical potential of wave energy is available South and Southwest of Aran Island. The lowest potential can be seen in the north and northeast regions, as seen in Figure 6.37 in the RE resources appendices. It shows the mean annual power potential of up to 60 kW/m along the south and southwest coasts, and a minimum of up to 15 kW/m potential is available along the north and northeastern coasts. Looking at the available potential, the region around Aran Island has the required minimum power potential of 15 kW/m (Denny & Keane, 2012).

3.3.1.3 Accessibility

Figure 6.38 in the RE resources appendices represents the percentage accessibility of sites set by Selkie Coastal Wave Atlas (CWA) for the whole year taking H_s 1.5 m and wind speed 20 m/s as their limits. These are usually the normal limitations of a Crew Transfer Vessel (CTV) (HORGAN,

2020). It is highly encouraging to note that since the availability of the weather window is calculated based on wave and wind data, the least accessibility ranges from 30-50% on the south and southwest coast which has the highest power potential. The most accessible locations are north and northeast, with access ranging from 50% to 100% over the entire year.

Figure 6.37 in the RE resources appendices presents the annual % accessibility of locations given Hs limits of 2 m and wind speed 15 m/s, representative of typical limitations for a Heavy Lift Vessel (HLV) (HORGAN, 2020). The spatial pattern is similar to that in Figure with a similar range of values. The entire coastal area of Aran Island is blessed with an average of 50% accessibility throughout the year, making the whole region ideal for WEC deployment.

3.3.1.4 Water depth and seabed characteristics

The coastal region around Aran Island is within the threshold limit of a maximum 300 m water depth for Wave energy converter deployments (O’Connell et al., 2023). The Figure 6.40 in the RE resources appendices, the maximum water depth in the area is 150 m, which is well within the limit for WEC deployments.

This section covers the classification of seabed characteristics, from sand to hard rock substrate. There are 7 folk classifications in Figure 6.41 in the RE resources appendices ranging from most favourable to least favourable. The seabed is essential and relevant for excavating WEC anchors and cable trenches. The softer the seabed, the easier the deployment of wave energy converters. Figure 6.42 in RE resources appendices also depicts the yellow areas, which are those excavatable to shore, and grey, which are those not excavatable to shore (O’Connell et al., 2023). The rock and hard substrate distribution in the region of Aran Island extends over 4 to 7 km and is not excavatable, but WECs can be easily deployed out of this region.

3.3.1.5 Marine traffic

The AIS density modelling layer for general shipping reveals that the busiest region is the north of Aran Island, which connects it with the mainland via ships and ferries. This is also visible in the Figure 6.43 in the RE resources appendices.

The fishing traffic is denser compared to general shipping. The spatial distribution of AIS density can be seen in the Figure 6.44 in the RE resources appendices. The regions in the southwest, north, and east of Aran Island are busiest for fishing traffic, but there is still enough area available to deploy WEC while avoiding the shipping routes.

3.3.1.6 Subsea cables

The Figure 6.45 in RE resources appendices shows the only subsea cable providing electricity to Aran Island from the mainland. It shows that the cable does not present an obstacle to the deployment of wave energy converters in the region of Aran Island.

3.3.1.7 Protected areas

The Figure 6.46 in RE resources appendices shows all the protected areas including SACs and SPAs in the coastal region of Aran Island. The protected areas mean WEC can't be deployed into those areas (Denny & Keane, 2012). Even excluding all the protected areas as non-potential for WEC deployment, Aran Island possesses a lot of other possible sites outside these protected areas where WEC can be easily deployed.

3.3.2 Wave annual energy production map

The online GIS model from the Selkie project also gives the annual energy production layer for different types of WECs. This resources assessment selects only the AEP layer for the point absorber type WEC. This selection was because the Republic of Ireland has finalized a Saoirse project of 5 MW capacity off the Co Clare coast (European Commission, 2024). For Aran Island,

it's more feasible to go with the same technology keeping the O&M requirements, as a similar project in the closer vicinity will help in sourcing the resources easily.

The Project will be developed by the joint venture of ESB and Simply Blue Group. The chosen technology for deployment is CorPower Ocean's WECs which is a point absorber-type technology (Corpower Ocean, 2023). The coastline of Aran Island has an annual energy production AEP potential ranging from 2,837 to 5,189 MWh/yr/MW.

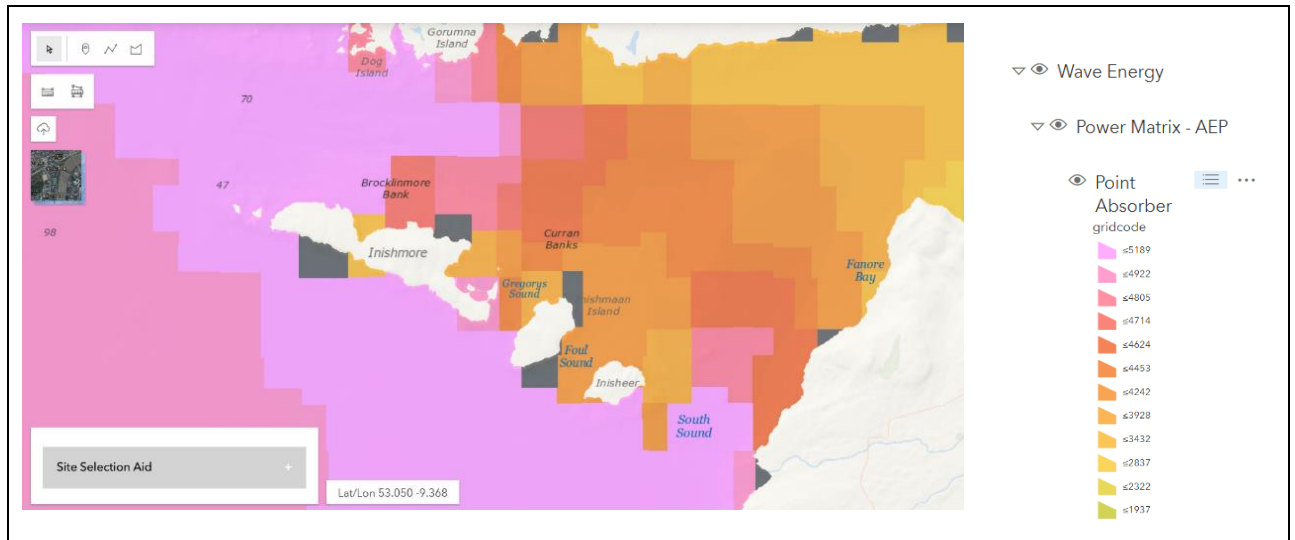


Figure 3.9. AEP for point absorber type WEC

Source: Selkie Project Web-Based GIS (HORGAN, 2020)

3.3.3 Annual hourly energy generation

The annual hourly energy generation curve has been generated using the data available in EnergyPLAN model for Ireland, which is developed by the Sustainable Energy Planning Research Group at Aalborg University in cooperation with PlanEnergi and EMD A/S (Aalborg University, 2020). The data has been analysed for conventional wave energy converters not specifically for point absorber technology. The study uses the time series data knowing the limitation of date and unavailability of readily available data for Wave energy technology. The generation curve is developed externally using Excel which is stated below in Figure 3.10. After analysing the time series data, it shows that the generation is high in winter from November to March, and the generation drops during summer from April to October.

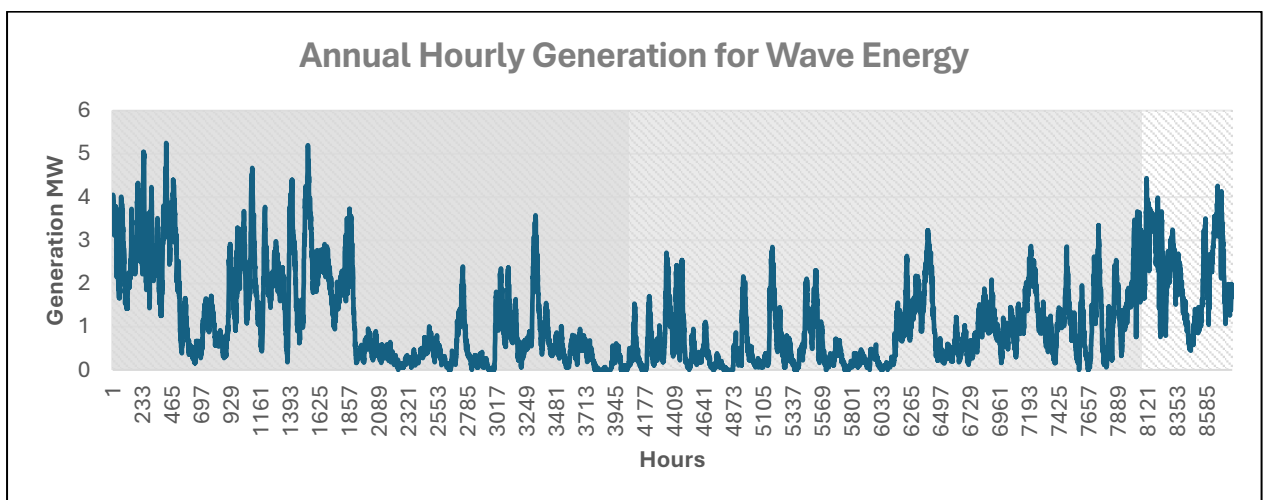


Figure 3.10. Wave energy annual hourly generation

3.3.4 Wave energy converter selection

Among current WEC developers, Pelamis and CorPower are distinguished by their technologies related to harnessing ocean wave energy. Here in Table 3.14 is a comparative overview that helps us in deciding a favourable WEC technology for Aran Island.

Table 3.14. Wave energy converters comparison

Sources. (CorPower, 2025a; Jahangir et al., 2023)

Comparison Matrix	Pelamis	CorPower Ocean
Technology and Design	Ideally designed for offshore deployment in deep seawater. Elongated structures float on the water's surface, which converts wave motion to electricity. Need long distance area.	It's a buoy with a point absorber-type technology. Oscillate with waves and convert it to energy. Need minimal area and can be deployed nearshore and offshore.
Performance and Efficiency	The structure flexibility causes a lot of efficiency challenges.	The advanced phase control technology helps in achieving more energy output compared to conventional WEC.
Survivability and Maintenance	In harsh weather ocean conditions, it has durability issues because of its elongated structure.	The buoy submerges during harsh weather conditions thanks to the storm protection mode design.
Status and Commercial Viability	Due to technological limitations and financial constraints, technology has been discontinued.	The technology is well on its way to commercialization, with one large-scale pilot project underway in Portugal and one just into commercial close on Co. Clare, Ireland.

After going through this comparison overview table and knowing the selection of CorPower technology for Saoirse Project 5 MW in the first phase on the Co. Clare coast and the later phase will be scaled up to 30 MW by 2030 in Ireland provides a good option for Aran Island as well (CorPower, 2025b). The success of this project will help in easing the O&M-related issues and knowledge curve for the same nature of the project in this region. Other than these two technologies, all others are in the testing phases, which is why they weren't considered for comparison in this study.

3.4 Offshore wind

Refer to the RE resource appendices under other technologies.

3.5 Tidal

The resource assessment concludes that no tidal energy potential is available, please refer to the RE resource appendices under other technologies to see the results.

3.6 Storage

In this project, two types of battery storage systems are considered, the first one is decentralized home systems in corporation with rooftop solar systems, and the second one is centralized battery storage system.

3.6.1 Decentralized storage for solar home systems

For rooftop solar systems, we assumed an average battery capacity of 5.3 kWh for each household with PV rooftop system. The specifications provided in the Table 3.15. The background behind this assumption is smaller size household, 2.7 people/household. Furthermore, we also noticed this battery capacity in different houses, from single person to 5 people household, during our visit for collecting data and conducting interviews. The cumulative capacity of the storage would be 2.66 MWh if all 502 permanently occupied households install similar batteries.

Table 3.15. Technical specifications of rooftop solar storage system

Data source: (WeCo, 2025), (Solis, 2025)

Parameter	Value	Units
Capacity per system	5.3	kWh
Depth of Discharge	95%	-
System efficiency	95%	-
Number of houses	502	-
Max storage capacity	2.66	MWh
Max storage power	1.45	MW

The total investment cost for the storage system solar home system includes the capital expense and operational expense. With the shipping cost included the total investment cost sums up as 2,340 euro/system. The replacement cost of the system after the end of its lifetime can be estimated as 2,252 euro/system.

3.6.2 Centralized storage system

For centralized system, Tesla Megapack 2 XL was chosen with the consideration of maximum demand and marginal economic benefit. Table 3.16 provides the specifications of the system.

Table 3.16. Technical specifications of central storage system

Data source: (Tesla, 2025)

Parameter	Value	Units
Capacity	3.9	kWh
Max storage power	0.95	MW
Initial storage	50%	-
Depth of discharge	95%	-
Inverter capacity	1.6	MVA
System efficiency	94%	-

The battery cabinet of the chosen system costs 0.9 million euro (Tesla, 2025), but the given the physical characteristics of the system, the total investment cost increases twofold. Considering the engineering procurement and construction (EPC), interconnection and permitting fee, and shipping cost, the total investment cost sums up as 1.89 million euro (NREL, 2024). The replacement cost at the end of 15-year lifetime can be estimated as 1.2 million euro.

3.7 RE regulations

Main effective policy documents to support sustainable transition in has considered in renewable energy generation listed below.

- National Energy and Climate Plan (NECP) 2021-2030
- Mission: A Green New Deal: Irelands obligation under EU Grand deal 55 package Framework
- Climate Action Plan 2024- Annual plan under long term plan
- National Recovery and Resilience Plan
- Small Scale Renewable Energy Support Scheme (SRESS/RESS)
- Community Energy Grant Scheme
- Microgeneration Support Scheme

3.7.1 Incentive mechanism

To support the renewable transitions the country introduces several mechanisms to accelerate and benefit to the RE generators. Few people had already received a support from these mechanisms on the Aran Islands, but to make the knowledge public main details has been described here.

3.7.1.1 *Small- Scale Renewable Energy Support Scheme (SRESS)*

Renewable energy feed-in-tariff scheme (REFIT) has been updated into Renewable Energy Support Scheme in 2020. The scheme is based on auctions and selected 15-20 RE projects as beneficiaries. The Beneficiaries by signing implementation contract become eligible to part of the scheme and from energy companies (retail suppliers) the letter of offer and enter PPA. The aid will be provided to retail suppliers who has PPA contract with beneficiaries. The payment mechanism is called a feed-in-premium (FIP) which involves reference price (market price) and strike price (guaranteed price). If market price is under the guaranteed price the difference would be paid from retail suppliers to beneficiaries. If market price exceed beneficiaries would pay as market price. The support will continue 15-16 years depending on the project implementation. Which benefits RE generators income certainty and supports market mechanism. (European Commission, 2020) If Aran Islands got possibility to access or be part of wind projects the capacity range would fall under RESS category.

Main difference of RESS with SRESS is the policy does not have auction, and it is aimed for smaller generations. The policy would be effective until 2030 and planned to have 2 phases. First phase would be renewable self-consumers above 60 kW and under 1 MW and second one is communities owned export projects from 50 kW to 6 MW. Considering the CFOAT is developing a solar project, applying under 1 MW Community criteria would benefit 150 euro per MWh solar generated electricity (C. and C. Department of the Environment, 2025).

3.7.1.2 *Community Energy Grant Scheme*

To support community-based energy projects the grant scheme started in 2020. The project can apply to the funding and receive letter of offer. Through project 17 successful community energy project implemented as said by SEAI (Sustainable Energy Authority of Ireland (SEAI), 2024). But these 17 projects details were unclear.

3.7.1.3 *Microgeneration Support Scheme*

Domestic RE installation could apply to SEAI for capital grants. Additional under 6 kW non-domestic generation can benefits through Clean Export Premium and Clean Export Guarantees to receive benefits (C. & C. Irelandgov. i.e. Department of the Environment, 2022)

Table 3.17. Renewable energy generation supporting mechanism comparison

	SRESS (Small-Scale Renewable Electricity Support Scheme)	CEGS (Community Energy Grant Scheme)	MSS (Microgeneration Support Scheme)
Government responsible	Department of Environment, Climate and Communications (DECC)	Sustainable Energy Authority of Ireland (SEAI)	SEAI & DECC
Incentive targeted group	Community projects,	Community projects, public buildings.	Homes, and small community projects.
Installed capacity range	Up to 1 MW – Small renewable generations for export to the grid.	Targeted to increase energy efficiency and renewable upgrades.	Domestic - Up to 6 kWp Export excess generation to the grid.
Incentives	Feed in premium tariffs to sell the generated electricity to the grid	Grant to share of the project cost to upgrade the system	- SEAI grants up to €1,800 for solar PV. - Clean Export Guarantee (CEG): Market rate for surplus electricity sold.
Source	(C. and C. Department of the Environment, 2025)	(Sustainable Energy Authority of Ireland (SEAI), 2022(C. & C. Irelandgov. ie Department of the Environment, 2022)2022)	

3.7.1.4 EU Innovation fund

Considering the wave energy generation technology is not commercialized yet, the EU innovation fund could provide support in the adaptation of this technology, while the fund is aimed to invest in innovative approaches to reduce greenhouse gas emissions. Through the tender and selection of the best proposal the EU Innovation determines which proposals to fund and up to 60% in case of regular grants and 100% in case of competitive bidding funding each project will receive. Notably, the Innovation Fund had invested in wave energy in Ireland, and Ocean Energy Company has received €19.6 million in funding (European Commission, 2025).

3.8 Renewable energy technologies economic analysis

3.8.1 Net present cost (NPC)

The NPC is a financial metric used to calculate the total lifetime cost of an energy system. It considers all costs associated with the system, including the initial investment, operation and maintenance expenses, and decommissioning costs, over its entire lifespan. These costs are discounted to their present value, allowing for a fair and accurate comparison of different projects or systems.

The following formula has been used for NPC:

$$NPC = C_0 + \sum \frac{C_t}{(1+r)^t} + \frac{C_d}{(1+r)^T} \quad \text{Equation 3.1}$$

Where:

- Co : The initial investment cost (purchasing and installing Solar panels, Inverters, etc.)
- Ct : The operation and maintenance cost in year t
- r : The discount rate
- Cd : The decommissioning cost occurring at the end of the project's lifetime T

The variables and parameters listed in the Table 6.9 in the appendices were used as input to the excel model for calculating the NPC for all technologies. To account for the unique challenges of the Aran Islands, such as logistical constraints, higher labour costs, and construction limitations, an additional 30% was added to both the capital investment and O&M costs.

Using the above parameters, the NPC total cost for the technologies is calculated and is listed in Table 6.10 in the appendices.

3.8.2 Levelized cost of electricity (LCOE)

LCOE is one of the critical metrics, used to estimate lifetime costs per unit of generation of electricity-usually per MWh. It considers several financial parameters-initial investments, operating cost, energy production, discount rate, and decommissioning costs-over a project's lifetime.

The LCOE of each energy project is calculated using the below formulas:

$$LCOE = \frac{NPV_{costs}}{NPV_{energy}} \quad \text{Equation 3.2}$$

And,

$$NPV_{energy} = \sum_{t=1}^T \frac{E}{(1+r)^t} \quad \text{Equation 3.3}$$

Where:

- E is the annual energy production (AEP)

The LCOE of Wave energy is also calculated based on the Innovation fund scheme available. The possible maximum amount that can be generated via the innovation fund is around 40% of CAPEX.

The final LCOE for all technologies calculations was executed in Excel and summarized in the Table 6.11 in the appendices.

4 System integration

The integration model designed for the Aran Islands aims to balance the forecasted electricity demand, outlined in the previous chapters, with the supply from various renewable energy sources, including solar, wind, and wave power. It also incorporates the option of electricity storage and uses the national grid as a backup.

The primary objective of the model is to explore different scenarios for meeting local electricity demand while considering varying levels of sectoral electrification. By simulating these scenarios, the user can identify the optimal share of renewable energy required to: reduce dependency on the national grid, reduce greenhouse gas (GHG) emissions, and reduce costs in purchases from the grid and expenses in fuels.

A key priority of the model is to maximize the use of locally generated electricity for on-island consumption, rather than exporting it to the grid. Additionally, it calculates the costs and savings associated with different scenarios, allowing users to evaluate their economic benefits.

The modelling was primarily developed using Microsoft Excel, which will be provided to CFOAT as a user-friendly tool for scenario analysis. HOMER Pro software was also employed to determine the optimal installed capacity to supply the different demand of the scenarios based on the lowest cost.

4.1 Current status

4.1.1 Transmission and distribution

The Aran Islands are connected to the mainland by 3 MW sub-sea cable from Rossaveel, Galway. Although this cable is the backbone of electricity supply to Aran Islands, it has several limitations in terms of supply reliability, energy security and future expansion. The decreased supply security due to lack of redundancy in mainland connection was proven during the power outage caused by cable damage, which lasted several days in August 2016. The grid connection was re-established after two months, during this period the island faced hardships and an additional economic burden due to complete reliance on the diesel generators. Moreover, according to the Aran Islands' Energy Master Plan 2018, the sub-sea cable was found to be inefficient in terms of transmission losses. In 2017, 6741 MWh of electricity had been supplied from the mainland and only 2993 MWh had been consumed in the three islands, which resulted in 56% of significant transmission loss. 62% of the electricity is consumed by Inishmore, while Inishmaan consumes 13% of total electricity import (J. Rivas et al., 2018).

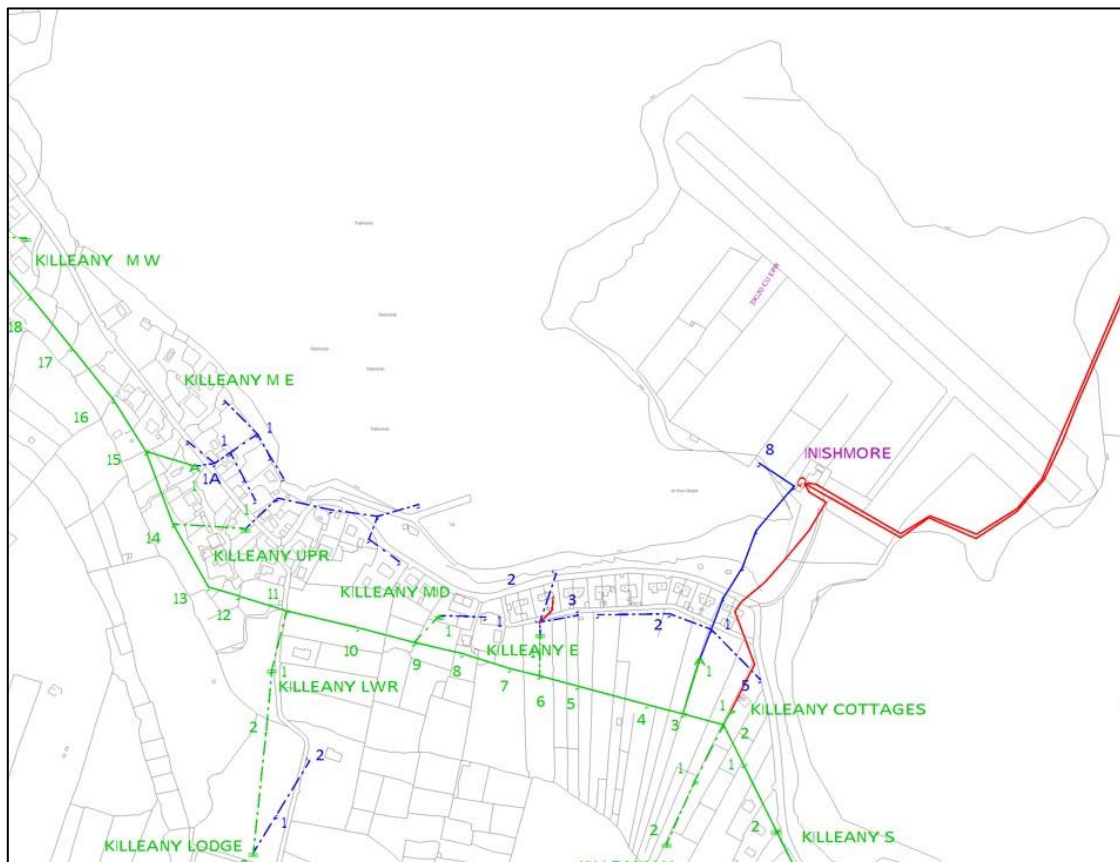


Figure 4.1. Snapshot of the transmission and distribution network

Data source: (ESB Networks, 2022)

The Aran islands have a medium-voltage distribution network of 20 kV as depicted in Figure 4.1, which is extended from the 20 kV sub-sea cable. The sub-sea cable has connected all three islands. In the meeting of the Joint Committee on Social Protection, Community and Rural Development and the Islands conducted in 2022, a limit of 650 kW regarding the export to the grid had been mentioned, which is imposed by ESB Networks. In the same meeting, a two-year limited window for acquiring the planning permission of any renewable energy technologies were also mentioned, after which the grid-connection offer will not be available (Maoildhia, 2022). The majority of households have single phase connections which limit their access.

4.1.2 Reliability

The Aran islands face harsh climate conditions and are connected to the grid via single sub-sea cable, and as such, their grid reliability is poorer than the mainland. From the time-series data received from ESB Networks, the grid's mean outage frequency was calculated as 3 per year, with a mean repair time of 2.68 hours, and repair time variability of 2.08%. The probability of outages has been portrayed in Figure 4.2.

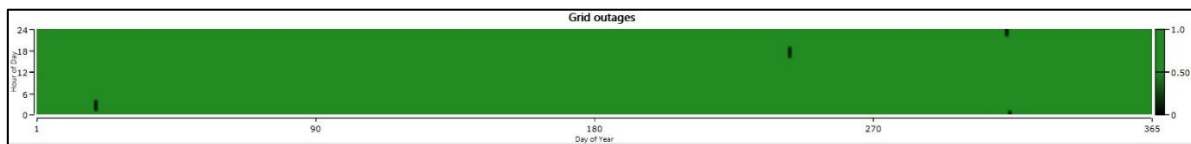


Figure 4.2. Probability of outages

4.1.3 Emission factor

The current emission factor of the electricity grid of Ireland is 254.8 gCO₂/kWh which is higher than EU average, indicating further actions necessary to decarbonize the national grid. The emission factor of the grid to be considered in the model for 2030 was projected as indicated in section 1.3. Historical emission factor of Ireland's national grid was obtained from SEAI for the period of 2005-2023. The retrieved data was forecasted to 2030, which resulted in a projected emission factor of 168.52 gCO₂/kWh (as illustrated in Figure 4.3). The forecast aligns with the Republic of Ireland's Climate Action Plan 2021 to achieve a reduction of 51% GHG emissions by 2030 (DECC, 2021).

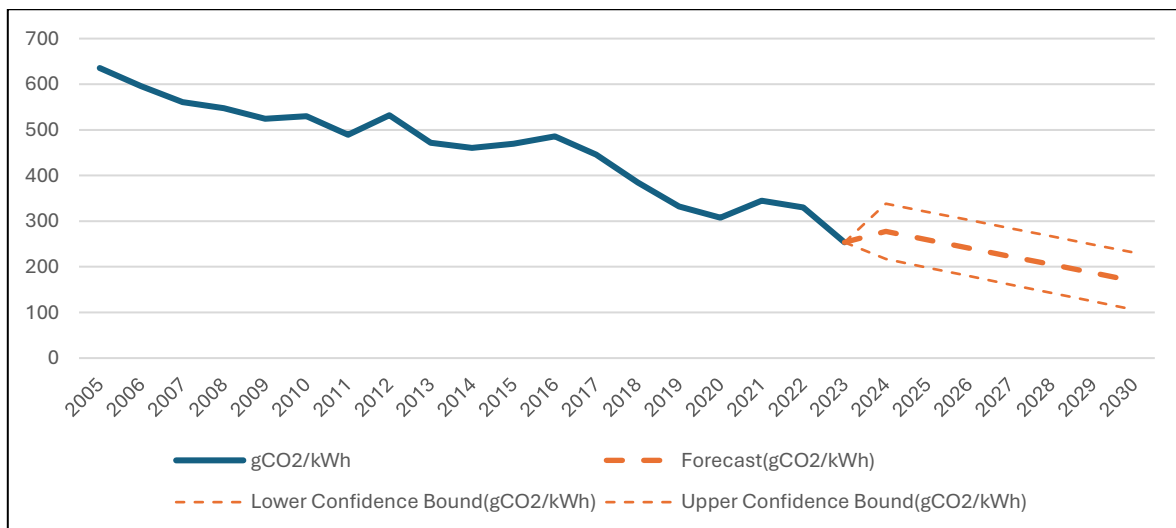


Figure 4.3. Grid emission factor forecast

Data source: (SEAI, 2024)

4.1.4 Tariffs

Ireland's electricity market operates as a unified system across both the Republic of Ireland and Northern Ireland, known as the Single Electricity Market (SEM). The SEM integrates the electricity industries of both regions into a single wholesale market. The SEM is jointly regulated by the Commission for Regulation of Utilities (CRU) in the Republic of Ireland and the Utility Regulator in Northern Ireland. Electricity suppliers, generators and traders are primarily involved in the SEM platform (Whitten & Robb, 2022).



Figure 4.4. Energy price trends in consumer level

Data source: (SEAI, 2025)

Figure 4.4 illustrates the historical trend of the average prices of electricity charged to the households and businesses. The residential users make contracts with the electricity suppliers, and the tariffs are structured to offer the consumers various options based on their usage patterns and needs. Traditional plans feature a fixed rate per kWh consumed, while smart meter plans provide time-of-use tariffs, charging different rates depending on the time of day (Electric Ireland, 2025). Day/Night plans can offer savings if a significant portion of the electricity usage occurs during nighttime hours, such as EV charging. Additionally, some suppliers may provide discounts, welcome bonuses, or green energy options which adds a premium to ensure the energy is from renewable sources.

In addition to the unit price of the electricity consumed which includes the profit margin of the supplier and taxes, there are annual standing charge which includes the fixed cost of the supplier, and a Public Service Obligation (PSO) Levy charge which is regulated by the CRU. Annual standing charge is higher in rural areas than urban areas, which affects the residents of the Aran Islands negatively. Furthermore, in 2024, CRU approved an added transmission and distribution charge around 100 EUR to be billed to the residential consumers, separate to the PSO Levy (Smith, 2024). Table 4.1 summarizes the charges and the current market offers.

Table 4.1. Tariff overview of different suppliers

Data source: (Bord Gáis, 2025), (Halpin, 2024), (Smith, 2024)

Billing Parameter	Market Tariff Range	Unit
Annual Standing Charge	218-356	EUR/year
PSO Levy	38.76	EUR/year
Unit Cost (Standard)	0.24-0.38	EUR/kWh
Unit Cost (Day/Night: Day)	0.26-0.42	EUR/kWh
Unit Cost (Day/Night: Night)	0.13-0.21	EUR/kWh
T&D Charge (TBI)	100	EUR/year
VAT	9%	
Estimated Annual Bill for an average household assuming 4,200 kWh/year	1,252-1,577	EUR/year

4.2 Modelling

4.2.1 Methodology

The accuracy, reliability and applicability of a model relies on the quality of the input data and the methodology chosen. In this case, two main tools were combined to obtain the base values for the simulations: Homer Pro, which is an optimization software, and a spreadsheet model developed using Microsoft Excel. Following a simple, yet efficient, way of creating the scenarios where the optimization function in Homer Pro represents the first step, followed by the flexibility and versatility of the Excel Model.

4.2.1.1 HOMER

Hybrid Optimization of Multiple Energy Resources (HOMER Pro) is a simulation and optimization software commonly used for numerous applications such as modelling hybrid renewable energy systems, designing microgrids, energy storage systems analysis, feasibility and sensitivity analysis. This configuration helps to sense the system synergy and contribution of each component as well as financial estimations and environmental considerations (Patil et al., 2023). The key parameters required as inputs for system design in HOMER Pro are load profiles, grid specifications and limitations, renewable energy resource availability, technological component specifications, economic inputs, project lifetime and emission constraints if any.

In this project, HOMER Pro was utilized to simulate and optimizing the system, define the system boundaries and identify suitable system configurations in each scenario based on the lowest cost. Hence, apart from discount and inflation rate and electricity selling price and feed-in tariff provided in the section 1.3, capital cost, operation and maintenance and replacement costs for each energy source were taken into consideration, which are provided in the Table 4.2.

To define the load profile, as shown in the Figure 4.5, annual hourly demand including general demand projected for 2030 (section 2.1.2), heating demand (section 2.2.3.8), EV demand (section 2.3.6.1), and electric cooking demand (section 2.4.2) were taken into consideration for different scenarios.

Table 4.2. Economic parameters of the system

Technology/ Parameters	Unit	Wind Energy	Solar Park	Rooftop Solar	Wave Energy	Home Battery Storage	Central Battery Storage
Max capacity	-	2.3 MW	1-17 MW	2 MW	1.2 MW	2 MWh	3.9 MWh
CAPEX	€/kW Or €/kWh	1,915	1,147	2,340	19,780	442	1,890
OPEX	€/kW Or €/kWh	66	16	23	120	10	8
Replacement cost	€/kW	-	-	-	-	425	1,188
Lifetime	Years	20	20	20	20	10	15

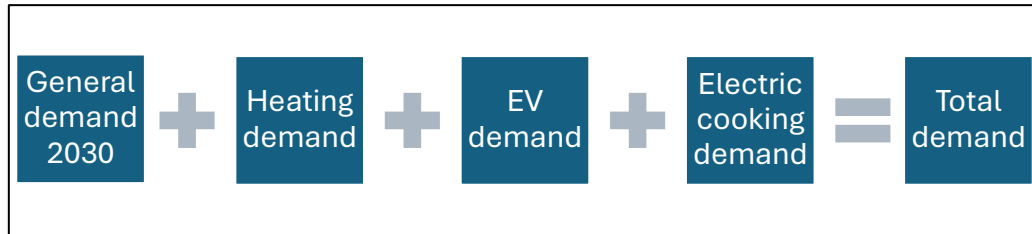


Figure 4.5. Simplified load profile calculation process

After collecting all demand data and importing load profiles into the system, energy sources were added to the system, including solar energy, wind energy, wave energy, battery storage and grid.

Concerning solar energy, two scenarios were developed, namely rooftop solar system and central solar park. In order to have a more precise simulation, initially, rooftop solar system buildings' orientation was also considered; this data stemmed from RE solar team studies in section 3.1.2 on categorizing buildings based on their orientation namely, south, south-west, south-east, east and west. These different categories, indicated in detail in the Table 4.3, were supposed to be modelled as 5 different solar systems in HOMER Pro with slope angle of 35 degrees. Furthermore, for economic analysis of rooftop solar systems, economic parameters of a 4 kW as a generic rooftop design were considered in the simulation.

Table 4.3. Roof top solar systems categories

Parameters	S1 (S)	S2 (SW)	S3 (SE)	S4.1 (90E)	S4.2 (90W)
Orientation	180	225	135	90	270
Number of systems	312	208	116	90	90
System size (kW)	4	4	4	4	4

However, due to limitations in number of optimizations in HOMER Pro, which allows user to optimize only 4 types of system at the same time, all rooftop systems with different orientations were considered as one system facing south, the orientation with the most availability of number of rooftops. It is also worth mentioning that total electricity generation in this case with all rooftop

PVs facing south (1,711 MWh/yr) was compared to the electricity production value provided by RE solar team from 4 different orientations (1,740 MWh/yr), and the result was a negligible difference of 1.67% between them.

For modelling solar parks, resource availability analysis derived by RE team in section 3.1.1 suggests that there is a potential of up to 17 MWp in 12 individual solar parks in the Aran Islands. Since economic parameters for solar parks, provided in the Table 4.2, are different from rooftop PV systems, related data was entered into model with a 30-degree slope angle and orientation of 180 degrees facing south.

To simulate wind energy, two locations were selected by RE wind team and then, the wind turbine selected by RE wind team in section 3.2 were added to the system simulation with economic parameters provided in the Table 4.2. For a more precise output, annual hourly wind speed and electricity generation were imported to the model, and finally, the monthly mean wind speed at the height of 78 meters was imported into the model as the wind resource.

The next step was to model wave energy in the HOMER Pro, and since it is not possible to directly model wave energy in the software, hydrokinetic energy was selected for modelling purposes. After entering economic parameters, the annual hourly energy generation profile provided by RE group in section 3.3 was imported to the model and since there was no data available representing water speed, an annual hourly water speed profile was generated utilizing artificial intelligence, and the conducted data was imported into the model.

Finally, to increase self-consumption and the system balance, two battery storage systems were defined. The first one was a decentralized home battery storage in corporation with rooftop solar system, and second one was a centralized battery storage system in corporation with all renewable energy sources. For home storage, a 5.3 kWh battery and for centralized storage system, a 3.9 MWh battery storage system were considered and then, economic characteristics of each system was entered into the model.

As a result, different scenarios indicating divers contribution from various technologies will be provided by HOMER Pro optimizer. These scenarios are based on levelized cost of electricity (LCOE), net present cost (NPC), CAPEX, OPEX and system energy balance, while grid purchases and electricity sold to the grid are taken into consideration in LCOE calculations.

4.2.1.2 Microsoft Excel based model

The Excel Model follows the logic represented in a summarized way in Figure 4.6.

It can be observed that the model has two main processes occurring in parallel, the first one corresponds to the residential PV systems (lower part of the flow diagram) including its batteries installed and the other section corresponds to the whole island including the possibility of a central storage. The Model depends on several inputs such as generation per technology and demand per sector, these data must be presented for one year as an hourly time series.

The model will follow a logical sequence of analysing the residual load at every hour. In the case of a positive residual load, meaning a higher demand than the supply, the system tries to deduct from the storage. In the opposite case, the system tries to store the excess in the battery system. The next step will be to analyse again the residual load, in the case of still existing unmet demand, the system will opt for grid purchasing, but in the case of excess of production that can't be store, the system will sale this excess electricity to the grid. The last consideration is when the grid limit has been reached and no more electricity can be sold, then it will curtail the excess.

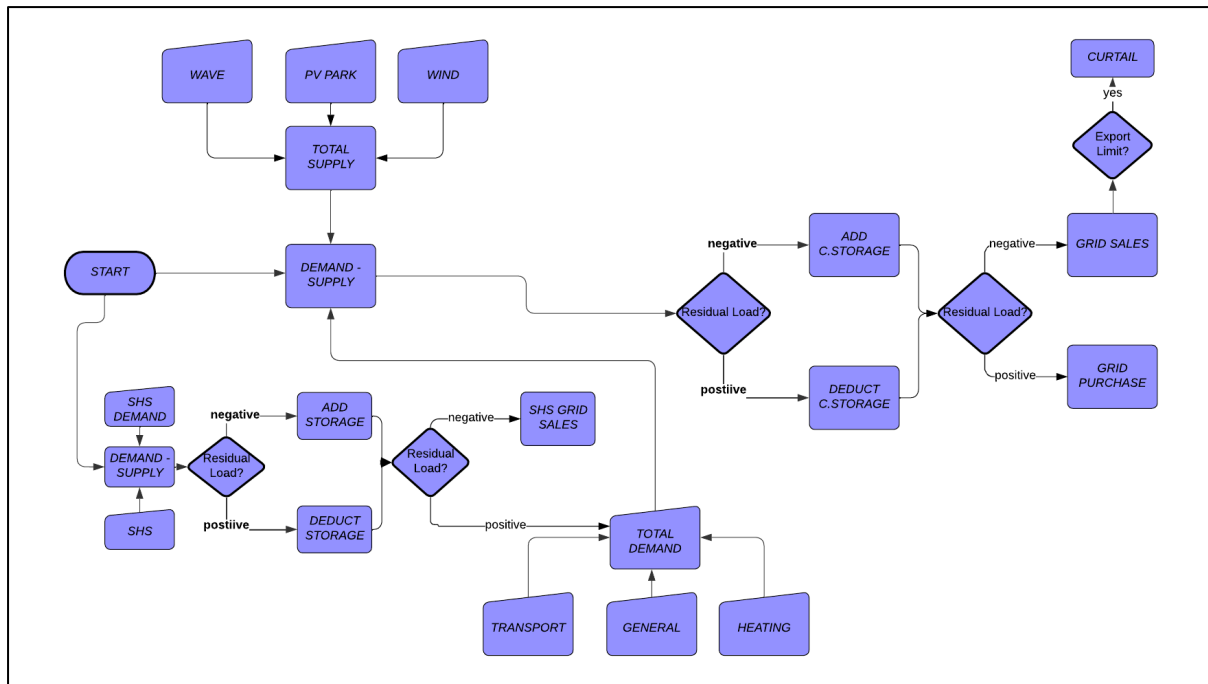


Figure 4.6. Excel model flow diagram

The Model was developed as an analytical tool to help in the decision-making process. Unavoidably it has a series of limitations that must be considered for results interpretation. Among these limitations are:

- The three Aran Islands were considered as one and the Model cannot differentiate between any of the three Islands.
- The Model considers the entire SHS in the island as a group and don't discriminate between generation and demand for individual households.
- The battery in the system will always be considered for discharging, if needed, in the immediate next hour.
- No distribution grid losses on the islands were considered for the analysis of grid purchases nor grid sales. It was assumed that the values presented correspond until the local recloser and not afterwards.
- The Model does not consider any grid capacity constraints, except for the one established towards the max power that the island can inject to the grid, set at 650 kW.
- In the cost section, the Model does not consider any fixed costs related to grid usage or user contracts.

The economic analysis of the model includes the calculation of the Net Present Cost (NPC) of the entire system, total CAPEX, CAPEX by technology and sector, revenues from electricity sales to the grid, savings from reduced grid purchases, fuel savings in the heating and transport and net saving of the system. The costs calculation covers the renewable energy generation and storage, electrification of cooking, heating, and transport costs over a 20-year project lifetime (2030–2050).

The methodology begins by calculating the initial investment costs in 2030 for each renewable energy technology, based on their installed capacity and capital costs. It then estimates annual O&M costs and accounts for replacement costs of components with shorter lifespans (e.g., batteries). All future costs are discounted at a 4% social discount rate (Chapter 1.3) and adjusted for an annual inflation rate of 2%.

The model also calculates the retrofitting investment needed for the heating sector, including the installation and maintenance of heat pumps, as well as the investment in electric vehicles (cars and buses) and the development of a centralized charging station. All costs are then integrated to provide an overview of the complete system.

4.3 Definition of scenarios

Three scenarios were developed following stakeholder engagement with CFOAT as the primary stakeholder and aligning with its Objective 4 outlined in the project's general goals. Additionally, these scenarios consider the key criteria identified as priorities by the local community during visits and engagement events, as summarized in Table 4.4. These priorities include reliable electricity access, cost minimization, reduction of GHG emissions, and increased independence from the national grid. The scenarios provide stakeholders on the Aran Islands with distinct pathways for transitioning to more sustainable energy sources.

The stakeholders were asked the following question: if a renewable energy system is implemented in the Aran Islands, how important are the following aspects to you? Please rate each from 1 to 5, where 5= is the most important and 1= is the least important.

Table 4.4. Surveys to community about relevance criteria of an energy system

Criteria by Person	Low costs	Low CO₂ emissions	Reliability of energy supply	Independence from the grid
Person A	4	5	5	3
Person B	5	3	5	5
Person C	5	3	5	4
Person D	4	5	4	3
Person E	3	4	5	4
Person F	4	2	5	5
Person G	2	4	5	3
Person H	5	2	4	3

The demand for each scenario is divided into four categories. The first is general demand, which includes a forecast for 2030 covering lighting and appliances continuing with the same path that has the island today. The other categories are per sector and account for cooking, heating, and transport, all considered under the scope of electrification, as the model focuses exclusively on this aspect. Residential solar systems, whether rooftop or ground-mounted, are referred to as solar home systems in the analysis.

To create a sense of connection with the local heritage and environment, the scenarios were named with materials historically significant to the Aran Islands and that are part of their landscape.

4.3.1 Scenario Do Nothing More (DN)

This scenario represents the current energy situation on the Aran Islands, projecting only the general demand (lighting and appliances) to 2030. It assumes no implementation of new energy transition plans and no further electrification of other sectors. Serving as a baseline, this scenario allows for comparison with alternative pathways to analyse the benefits of transitioning versus maintaining the current status.

4.3.2 Scenario Wool

Like the soft wool that has provide warm for islanders during many generations, this scenario provides a smooth advance in the implementation of renewable energy in Aran Islands with low disturbance in the lifestyle of islanders and continuing with the current plans of solar home systems.

It ensures electricity supply to meet the general demand projected for 2030, without accounting for increased electrification in the heating and transport sectors. In this scenario, the community still relies on fossil fuels and the national grid but increases the use of local renewable energy. It is designed to be affordable, have a low visual impact, and have higher acceptance by the community. However, wool also can be weak to affront challenges in the security of electricity supply as long blackouts of the grid.

4.3.3 Scenario Sand

Like the sands along the Aran Islands' coastline, constantly reshaped by the changing tides, this scenario represents a more significant shift toward electrification and a larger increase in renewable energy capacity compared to the Wool scenario. It aims to move the community further away from grid dependency while remaining flexible and resilient. This scenario addresses the general electricity demand projected for 2030 and includes additional electrification measures: 15% adoption of electric cars, 250 homes using heat pumps, representing a 35% increase in heating electrification, and 50% electrification of cooking.

This scenario is well-suited for a moderate investment and higher GHG reduction without requiring drastic lifestyle changes.

4.3.4 Scenario Stone

Inspired by the strong limestone that forms the foundation of the Aran Islands, this scenario envisions a future where the community achieves near-complete energy independence, relying almost entirely on renewable sources. It represents the most ambitious pathway. The key features of this scenario include: 100% electrification of cooking and heating and full adoption of electric cars and buses.

The goal is to create a sustainable future while fostering a green economy that benefits the islands through local job creation, energy security, and environmental preservation. It requires a higher level of investment and commitment but offers the greatest long-term benefits in terms of grid independence, emissions reduction, and economic sustainability.

Table 4.5. Summary of demand scenarios

Criteria/Scenario	DN	Wool	Sand	Stone
General demand	100% of 1,400 people	100% of 1,400 people	100% of 1,400 people	100% of 1,400 people
Cooking demand	150 houses	150 houses	326 houses	502 houses
Heating demand	50 houses	50 houses	251 houses	502 houses
Transport demand	25 EVs	25 EVs	79 EVs	369 EVs 26 E buses

4.4 Results

4.4.1 Wool

4.4.1.1 HOMER model

In this scenario, based on the defined demand profile and availability of electricity generation technologies, HOMER Pro was utilized to optimize the system and reach a balance with optimum amount of grid purchases and minimum excess of electricity in the system. After running the optimization, HOMER Pro optimizer suggested having maximum number of rooftop solar systems, 2,008 kWp on 502 occupied residential buildings, with the minimum number of 51 home battery storage systems, which are already installed. HOMER does not incorporate more home battery storage in the system because optimization is cost-driven and there is a moderately high feed-in tariff for rooftop solar systems. Thus, home battery storage requires a significant capital cost, affecting the NPC and LCOE of the system.

However, by taking feasibility factor into account, having rooftop solar system on every building on the islands does not seem to be realistic in the near future. Therefore, after simulating various system configurations and analysing the results, a setup was chosen in which 1 MWp of solar capacity was installed on half of the occupied houses, with home battery storage (HBS) provided for all of them to enhance reliability in this scenario. It is worth mentioning that since HOMER's logic in calculating economic parameters like NPC was different from the model developed in the excel, data derived from HOMER optimizer were utilized in the excel model for further economic considerations. Results of simulation for the argued system configurations are provided in the Table 4.6.

Table 4.6. HOMER Pro optimization results of Wool scenario

No. of rooftop PVs	No. of HBS	Electricity generation (MWh/yr)	Grid purchases (MWh/yr)	Excess of Electricity (MWh/yr)	Capex (M EUR)	LCOE (EUR/kWh)	NPC (M EUR)
250	250	856	3,897	0	2.37	0.26	3.51
250	51	856	3,930	0.04	1.91	0.24	2.47

4.4.1.2 Excel model

The final supply parameters for Wool scenario, following the optimization results, can be seen in Table 4.7. These parameters consider not only the optimization results, but also social and technical considerations, that might not be represented in Homer.

Table 4.7. Wool scenario final supply parameters

Parameter	Value	Units	Equivalent
SHS Total Installed Size	1	MWp	250 Houses with a 4kWp SHS each
SHS Batteries Total Installed Capacity	1,325	MWh	250 Batteries with a 5.3 capacity each

In the Wool scenario, being the least ambitious scenario, the island's electricity generation increased only through SHS, resulting in a continued high dependence on the grid. As shown in Figure 4.7, 82% of the island's electricity consumption comes from grid purchases. Regarding the generation balance, Figure 4.8 illustrates that 88.6% of the locally generated electricity is consumed by islanders, while 8.7% is sold back to the grid. This is mainly due to the misalignment between peak solar generation—typically occurring at midday—and peak electricity demand,

which usually happens in the evening. As a result, any excess solar production during the day is available for sale to the grid.

Although batteries are installed as part of the residential SHS, their total storage capacity is insufficient to retain all the excess energy generated. However, their presence in the system contributes to efficiency losses, which account for 2.8% of the total energy consumption. Notably, in this scenario, no curtailment was necessary.

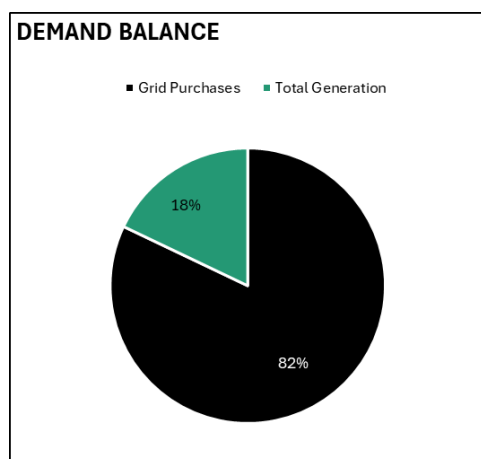


Figure 4.7. Wool demand balance

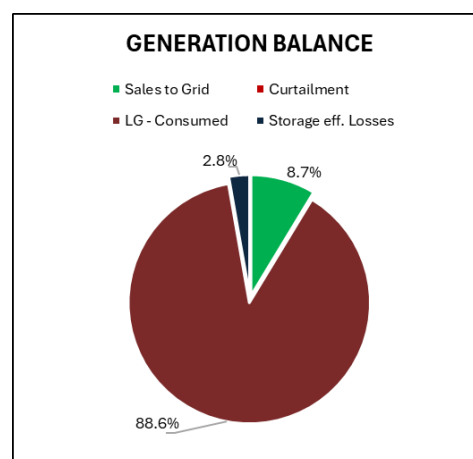


Figure 4.8. Wool generation balance

Since this scenario only considers SHS as generation on the island, the generation mix equals the one represented in Figure 4.7.

Figure 4.9 shows the emissions corresponding to imports from the grid and the exports made to the grid as emissions savings. In the Wool scenario, 723.3 tCO₂ net emissions were calculated.

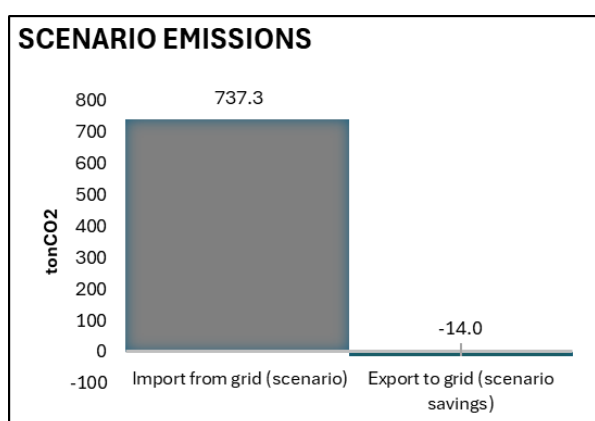


Figure 4.9. Wool scenario emissions

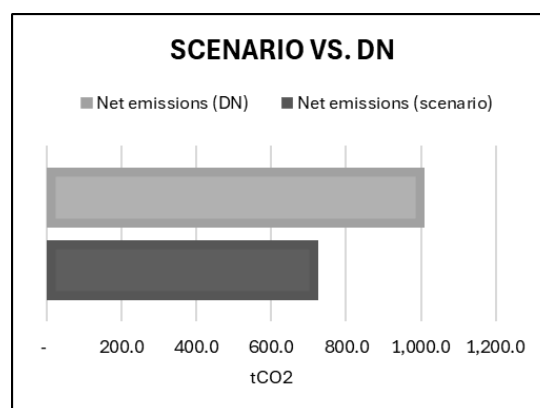


Figure 4.10. Wool emissions vs. DN

A comparison between the Wool scenario and Do-Nothing scenario is shown in Figure 4.10. It can be observed that even a low level of ambitions, makes a considerable change in the emissions, resulting in a net savings of 285.1 tCO₂.

The total investment cost of the system amounts to 1.69 million euro, fully assigned to renewable energy generation capacity, with no expenditure directed towards demand-side sectors. According to the CAPEX technologies chart (Figure 4.11), the largest portion of the investment, approximately 1.11 million euro, is dedicated to new SHS, followed by home solar system storage, which accounts for 0.59 million euro. No other technologies are considered in this scenario, highlighting its primary focus on expanding renewable energy supply rather than electrifying end-use sectors.

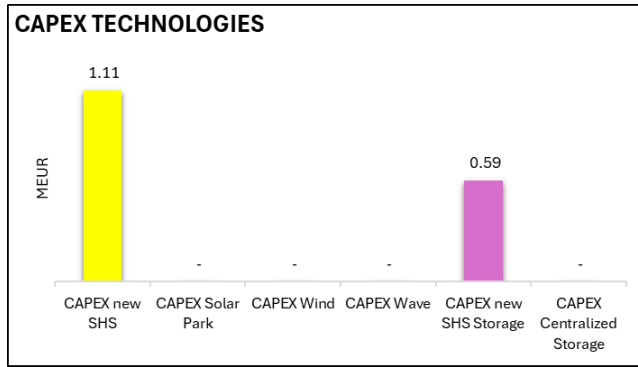


Figure 4.11. Wool capex per technologies (MEUR)

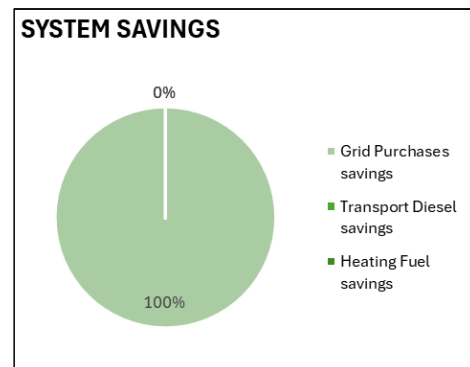


Figure 4.12. Wool system savings (MEUR)

For the DN scenario, annual grid purchases are estimated at 1.31 million euro, while the Wool scenario requires 1.18 million euro per year. This results in total system savings of 135,682 euro annually, savings mean the purchases avoided to the grid (Figure 4.12).

Over a 20-year lifetime, the system NPC is projected at 2.28 million euro after sales of surplus electricity to the grid, averaging 114,161 euro per year. When annual savings are deducted from the NPC, a positive balance of 21,521 euro per year is achieved (Figure 4.13).

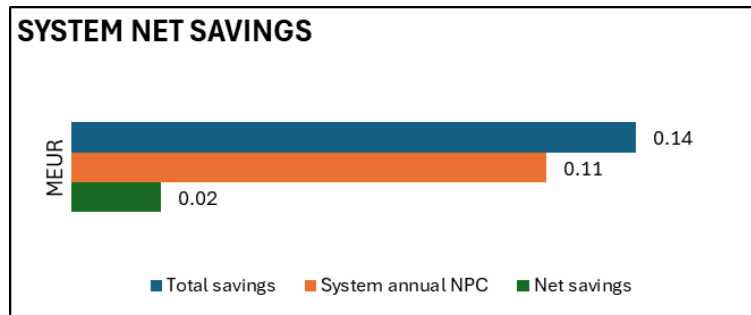


Figure 4.13. Wool system net savings

4.4.2 Sand

4.4.2.1 HOMER

In this scenario, overall demand aligned with a rise in the share of EVs to 15%, an increase in housing retrofitting, the adoption of electric cooking and heat pumps in 50% of households. Availability of technologies were also different in this case, adding possibility of having a solar park with a minimum of 1 MWp and maximum 17 MWp capacity supported with a 3.9 MWh centralized storage system. After running the optimization, HOMER Pro optimizer suggested a system setup with 1 MWp rooftop solar system on 250 occupied buildings and a minimum number of 51 home battery storage systems aligned with 1 MWp solar park.

Table 4.8. HOMER Pro optimization results of Sand scenario

No. of rooftop PVs	No. of HBS	Solar Park	Electricity generation (MWh/yr)	Grid purchases (MWh/yr)	Excess of Electricity (MWh/yr)	Capex (MEUR)	LCOE (EUR/kWh)	NPC (MEUR)
250	250	1	1,701	3,980	0.03	3.52	0.22	4.96
250	250	0	856	4,542	0	2.37	0.26	3.50

Results showed no adoption of central battery storage due to insignificant improvement in system balance while increasing the capital costs remarkably; however, same as the last scenario, 250 home battery storages were adopted to improve system's reliability regardless of

cost. Results of system simulation for the argued system configurations are provided in the Table 4.8.

4.4.2.2 Excel

The final supply parameters for Sand scenario, following the optimization results, can be seen in Table 4.9.. These parameters consider not only the optimization results, but also social and technical considerations, that might not be represented in Homer.

Table 4.9. Sand final supply parameters

Parameter	Value	Units	Equivalent
SHS Total Installed Size	1	MWp	250 Houses with a 4 kWp SHS
SHS Batteries Total Installed Capacity	1.325	MWh	250 Batteries with a 5.3 kWh capacity
PV Park Size	1	MWp	2,831 panels of 420 Wp

In the Sand scenario, representing the mid-level ambition, the introduction of a central PV park reduces grid dependence to 71%, as shown in Figure 4.14.

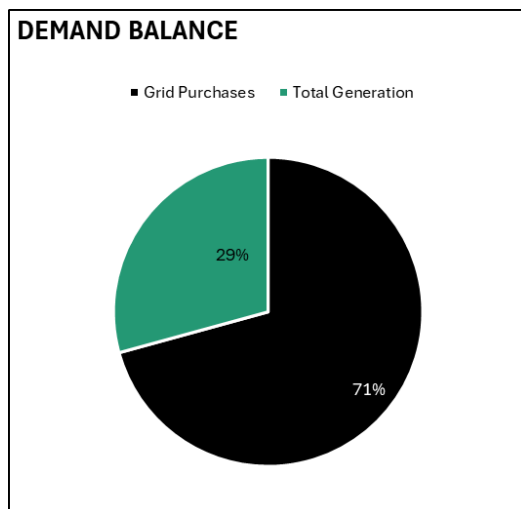


Figure 4.14. Sand demand balance

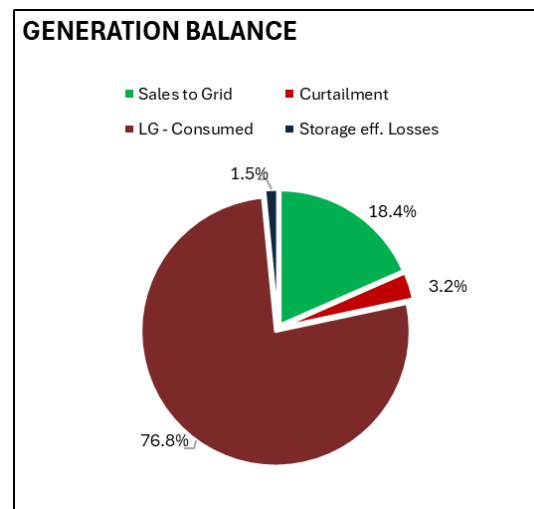


Figure 4.15. Sand generation balance

Figure 4.15 illustrates that 76.8% of the locally generated electricity is consumed by islanders, 18.4% is sold to the grid, 1.5% is lost due to storage efficiency losses, and 3.2% must be curtailed. This curtailment occurs because of the additional generation from the centralized PV park and the limited storage capacity.

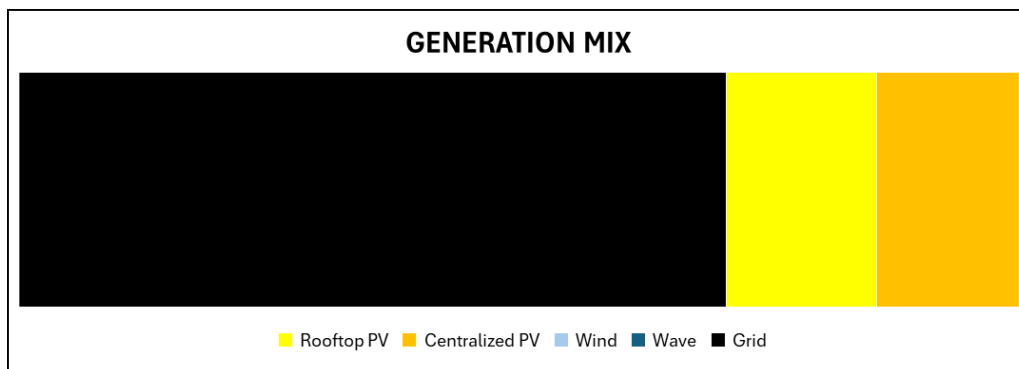


Figure 4.16. Sand generation mix

Figure 4.16 represents the generation mix for Sand scenario, where is possible to observe the grid dependency as stated before and the total generation that in this scenario is split into the two technologies involved: SHS with a 15.01% contribution and Centralized PV with a 14.25% contribution.

Figure 4.17 shows the emissions in Sand scenario, 701.1 tCO₂ net emissions were calculated wich is 22.2 tCO₂ less than the net emissions in Wool scenario. This reduction is attributable to the introduction of the PV Park since SHS is equal in both scenarios.

A comparison of Sand scenario versus Do-Nothing scenario, results in 307.3 tCO₂ net emissions savings, as shown in Figure 4.18.

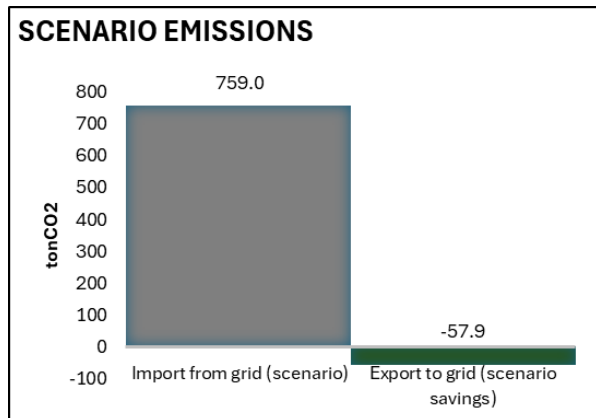


Figure 4.17. Sand scenario emissions

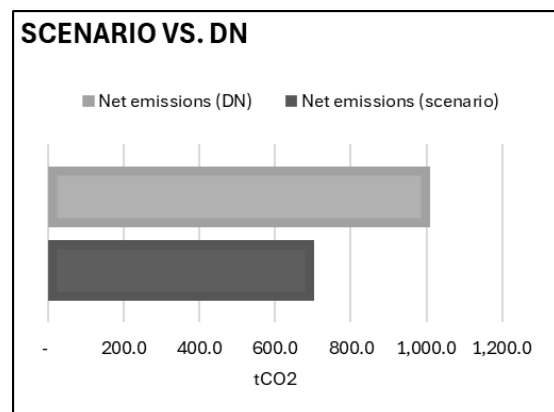


Figure 4.18. Sand emissions vs. DN

The total investment cost of the system in Sand amounts to 8.36 million euro. Of this, 61% is allocated to the heating sector, primarily for retrofitting. Renewable energy technologies account for 34% of the investment, followed by 4% for transport and 1% for cooking.

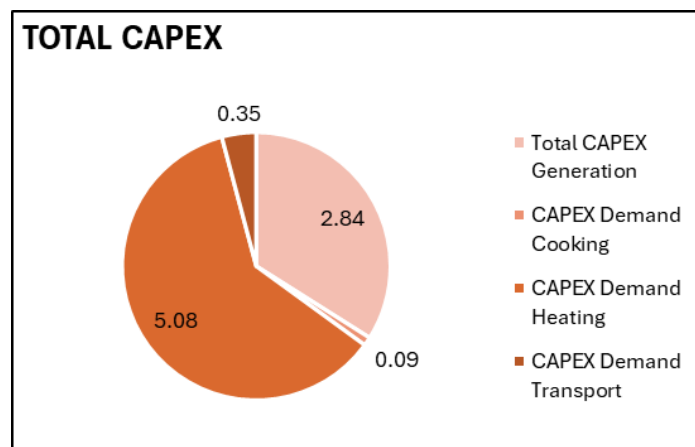


Figure 4.19. Sand total CAPEX (MEUR)

According to the CAPEX technologies chart (Figure 4.20), the total investment required to reach 1 MW of installed capacity is higher for a solar park compared to solar home systems (SHS). However, the cost per kWp is approximately 1,755 euro for SHS and 1,147 euro for a solar park. This difference arises because the model considers the existing installed capacity of solar panels on the Aran Islands, which is 370 kWp. Consequently, achieving 1 MW with SHS requires less additional investment since a portion of the capacity is already in place.

The system savings in Sand are estimated at 531,205 euro per year. Figure 4.21 shows that the most significant portion comes from fuel savings in the heating sector, accounting for 64% of the total. This is followed by savings from reduced grid electricity purchases (19%) and decreased

diesel consumption in the transport sector (17%). Notably, even a small increase in electric vehicle adoption, a 15% rise in this case, results in substantial savings, highlighting the economic benefits of transitioning to cleaner transport options.

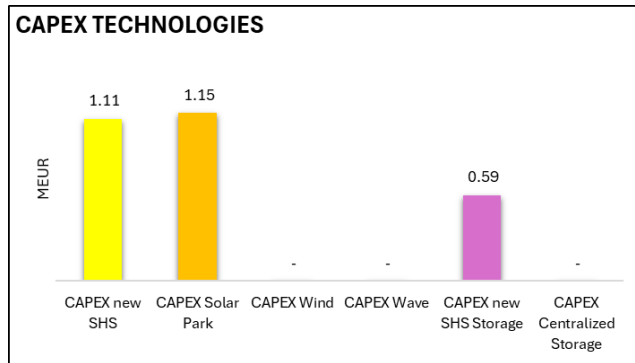


Figure 4.20. Sand CAPEX per technologies (MEUR)

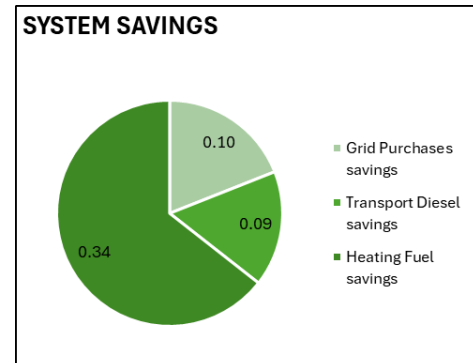


Figure 4.21. Sand system savings (MEUR)

Over a 20-year lifetime, the system's Net Present Cost (NPC), after accounting for grid sales, is projected at 9.0 million euro, averaging 450,097 euro per year. By deducting the annual savings of 531,205 euro from the NPC, a positive annual balance of 81,108 euro is achieved (Figure 4.22).

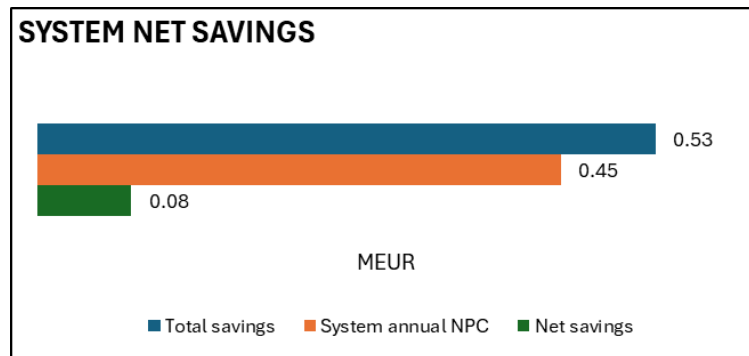


Figure 4.22. System net savings Sand

4.4.3 Stone

4.4.3.1 Homer

This scenario as the most ambitious one includes adoption of 100% EV, 100% electric cooking and 100% heat pump, making the total demand significantly higher than the two other scenarios. Moreover, in supply side, characteristics of a 2.3 MW Enercon wind turbine with high hub of 78 meters and a minimum 1.2 MW wave energy converter were added to the model as inputs; alongside with rooftop and solar park, centralized and decentralized battery storage systems. The optimization results outlined a system setup comprising a 2.3 MW wind turbine, 370 kWp rooftop PV system with 256 kWh of home battery storage and a 1 MWp solar park on the supply side without any centralized battery storage system included. Additionally, due to the high reliability of the optimized system on the grounds of resource variability, unlike two other scenarios, the number of home batteries was not increased in this scenario. In the Table 4.10, results of different systems from optimization are presented.

Table 4.10. HOMER Pro optimization results of Stone scenario

No. of SHS	No. of HBS	Solar Park (MWp)	Electricity generation (MWh/yr)	Grid purchases (MWh/yr)	Excess of Electricity (MWh/yr)	Capex (MEUR)	LCOE (EUR/kWh)	NPC (MEUR)
92	51	1	9,475	455	284.25	6.41	0.04	10.23
92	51	0	8,455	455	169.1	5.27	0.036	8.77

4.4.3.2 Excel

The final supply parameters for Stone scenario, following the optimization results, can be seen in Table 4.11.. These parameters consider not only the optimization results, but also social and technical considerations, that might not be represented in Homer.

Table 4.11. Stone final supply parameters

Parameter	Value	Units	Equivalent
SHS Total Installed Size	0.37	MWp	~92 Houses with a 4 kWp SHS
SHS Batteries Total Installed Capacity	0.27	MWh	~51 Batteries with a 5.3 capacity
PV Park Size	1	MWp	2,831 panels of 420 Wp
Wind Turbine Generator	2.35	MW	1 WTG

This scenario, with its most ambitious characteristics, requires the highest penetration of renewable energies. For which the WTG stated above was considered plus the PV Park. Important to notice that for Stone scenario, SHS was considered as existing capacities. In result, Figure 4.23 shows that the grid dependency is considerable reduced from 71% in Sand scenario to only 4%.

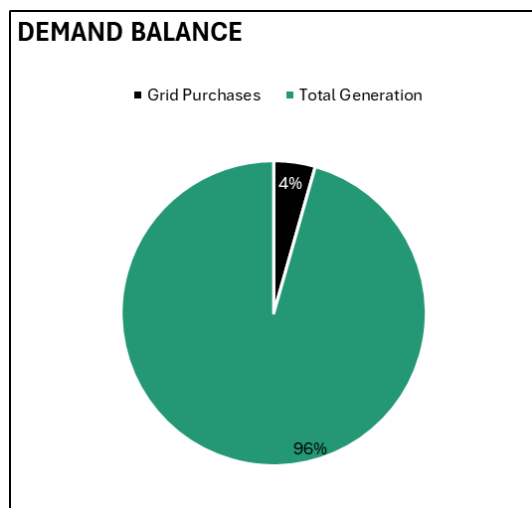


Figure 4.23. Stone demand balance

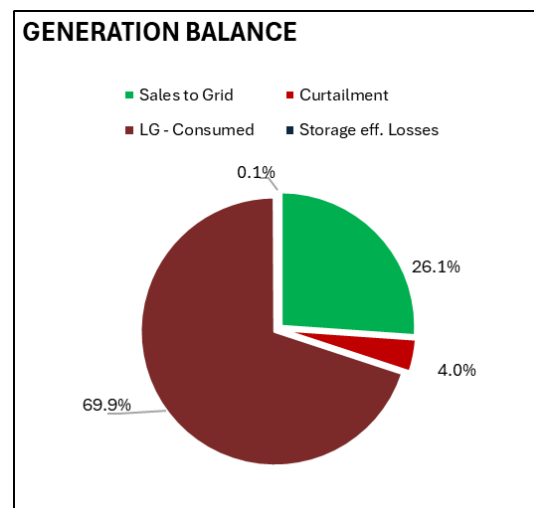


Figure 4.24. Stone generation balance

While Figure 4.24 shows that from the local generation, only a 4.0% must be curtailed and a 26.1% can be sold to the grid.

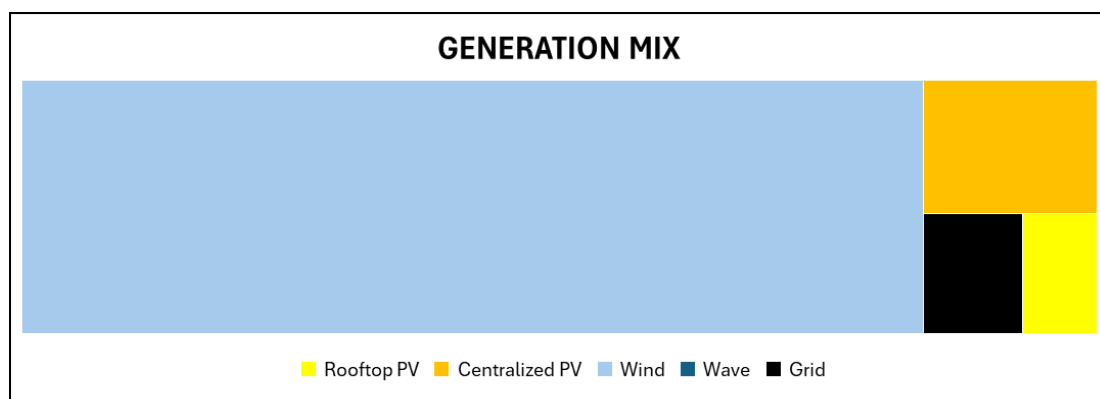


Figure 4.25. Stone generation mix

The generation mix for Stone scenario, shown in Figure 4.25, presents the high contribution from the WTG. A total of 83.84% is attributed to Wind energy, 8.48% is attributed to PV Park, 4.4% attributed to the grid and 3.28% attributed to SHS.

Figure 4.26 shows the emissions corresponding to the Stone scenario. Since this is the scenario with the highest renewable energy penetration, is also the one with the lowest net emissions with being negative (carbon credit), 370.7 tCO₂, emissions savings.

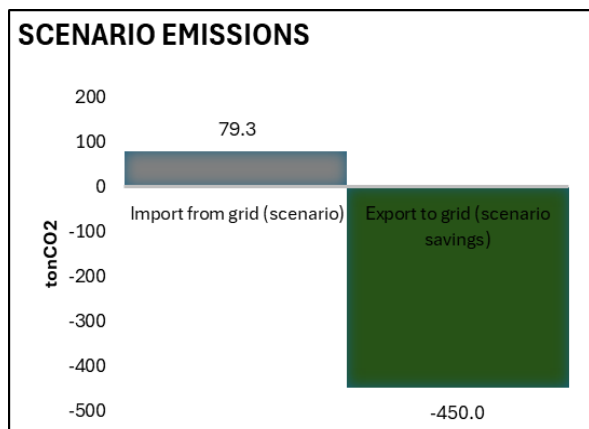


Figure 4.26. Stone scenario emissions

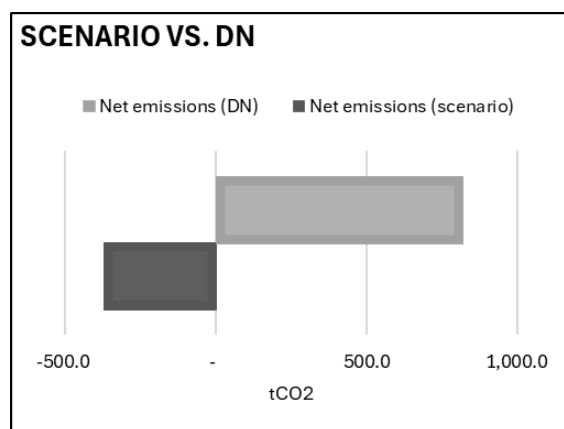


Figure 4.27. Stone emissions vs. DN

When compared against the Doing Nothing scenario, the resultant emission savings turns out to be 1,193 tCO₂ saved, as shown in Figure 4.27.

The total investment cost of the system in Stone amounts to 20.07 million euro. Of this, 39% is allocated to the heating sector, mainly for retrofitting, while 32% is directed toward investments in electric cars, buses, and supporting infrastructure. Investments in renewable energy technologies account for 28%, with the remaining 1% allocated to cooking (Figure 4.28).

Overall, 71% of the total investment is dedicated to the demand sector, while the remaining 29% focuses on renewable energy supply.

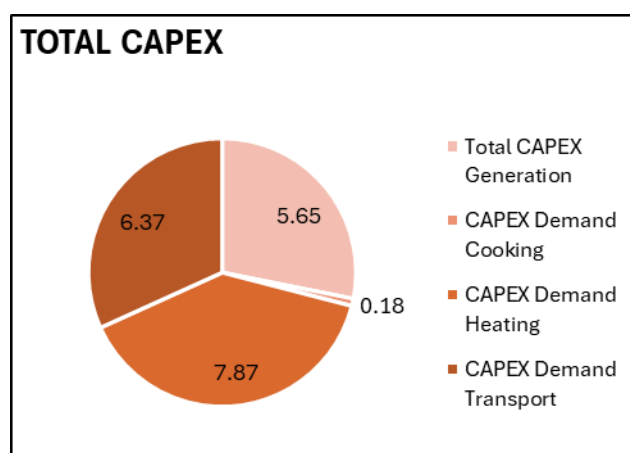


Figure 4.28. Stone total CAPEX (MEUR)

In this case, the investment by technology includes the installation of a 1 MW solar park, requiring a total investment of 1.15 million euro, and a 2.3 MW single wind turbine with an investment cost of 4.5 million euro. Notably, no additional expenses are allocated for energy storage systems in this scenario.

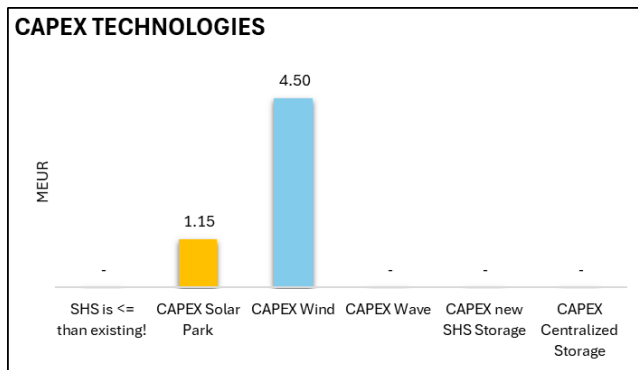


Figure 4.29. Stone CAPEX per technologies (MEUR)

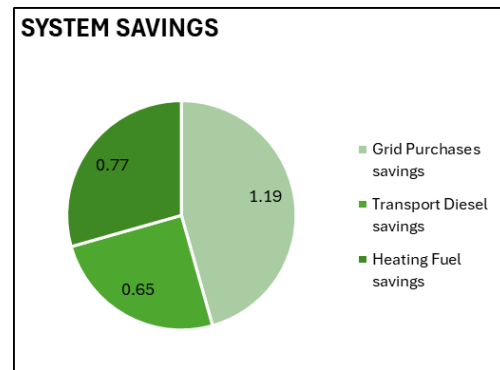


Figure 4.30. Stone system savings (MEUR)

In the Stone scenario, heating, cooking, and transport are fully electrified, with the energy system being nearly independent from the national grid and primarily supplied by local generation. This scenario achieves total savings of 2.6 million euro (Figure 4.31). Of these savings, 46% result from avoided electricity purchases from the national grid, 29% from reduced fuel costs for heating, and 25% from eliminating diesel purchases for the transport sector.

This is the most ambitious scenario, requiring the highest level of investment across all sectors. However, it also delivers the greatest overall savings and the highest net savings after accounting for the annual Net Present Cost (NPC). Notably, the net savings of four years (if they keep constant) are equivalent to the total investment needed for a 2.3 MW wind turbine. When the total net savings of a year are distributed among the 502 inhabited houses on the islands, after covering all investment, operation, and maintenance costs, each household could benefit from net savings of approximately 2,988 euro.

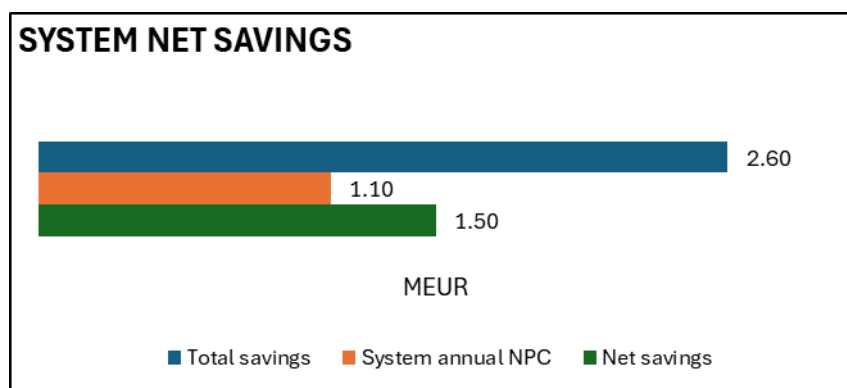


Figure 4.31. Stone system net savings

4.5 Scenario comparison

Comparison between demand in each sector for different scenarios is provided in the Figure 4.32. Based on the chart, while general demand dominates in all scenarios, heating demand due to different levels of retrofitting and adoption of heat pumps shows a more varied pattern in different scenarios, being moderate in the Wool but experiencing significant growth in Sand and Stone. EV demand remains quite steady but peaks in Stone scenario, where 100% EVs and electric buses are added to the system. Finally, cooking demand starts to appear in the Sand scenario with 50% electric cooking appliances and continues to grow up to 100% in Stone. Table 4.12 shows the summary of demand, installed capacity of technologies and storage for each scenario.

Table 4.12. Scenarios summary

Criteria/Scenario	DN	Wool	Sand	Stone
General demand	100% of 1,400 people	100% of 1,400 people	100% of 1,400 people	100% of 1,400 people
Cooking demand	150 houses	150 houses	326 houses	502 houses
Heating demand	50 houses	50 houses	251 houses	502 houses
Transport demand	25 EVs	25 EVs	79 EVs	369 EVs 26 E buses
Solar home systems	51 houses, 370 kWp	250 houses, 1 MWp	250 houses, 1 MWp	51 houses, 370 kWp
Batteries solar home systems	51 houses, 256 kWh	250 houses, 1 MW	250 houses, 1 MWh	51 houses, 256 kWh
Solar Park	No	No	1 MW	1 MW
Centralized storage	No	No	No	No
Wind farm	No	No	No	2.3 MW
Wave energy	No	No	No	No

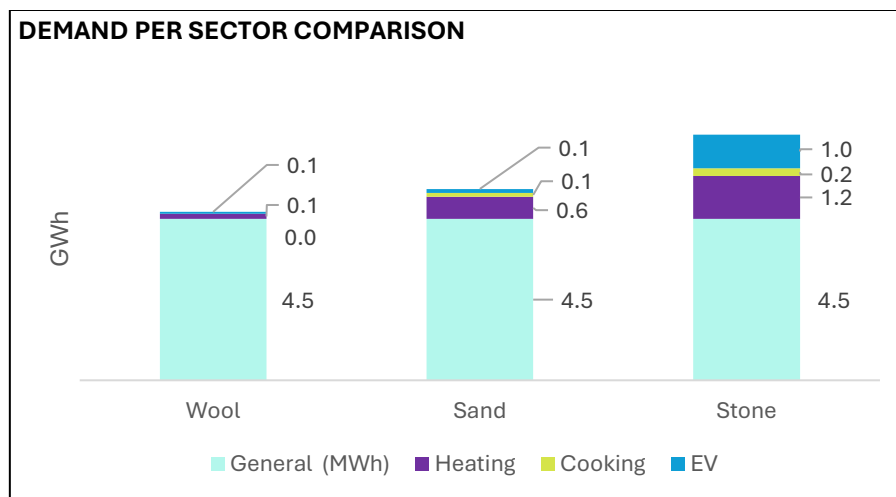


Figure 4.32. Demand per sector comparison

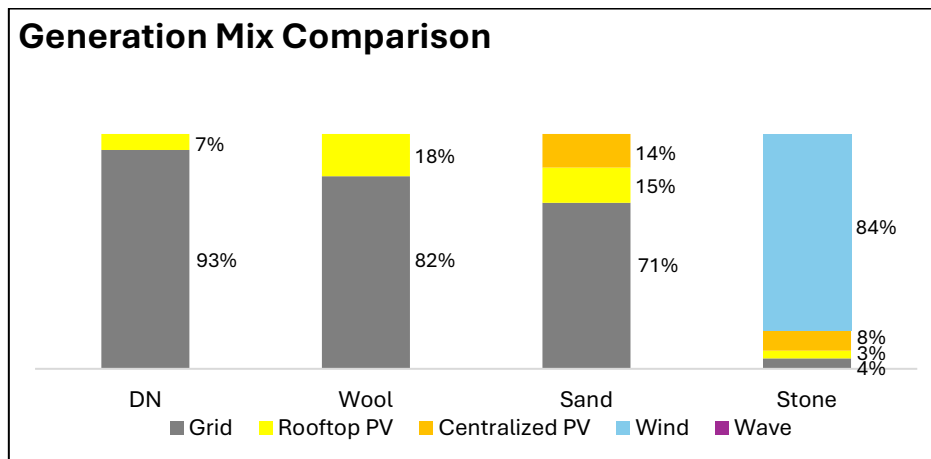


Figure 4.33. Generation mix comparison

Figure 4.33. illustrates how the generation mix varies across different scenarios. A more diverse energy mix provides multiple options for meeting demand, which can enhance the reliability and resilience of the electricity supply. The impact of diversification is evident in its direct relationship with grid dependency. In the Stone scenario, even in the event of a major failure—such as the subsea cable becoming inoperable—alternative energy sources would still be available to sustain demand. This ensures a more stable and self-sufficient energy system. In contrast, the Wool scenario does not offer this benefit, as it remains highly dependent on the grid and relies on only a single source of local generation. This lack of diversification increases vulnerability, making the system more susceptible to supply interruptions and external shocks.

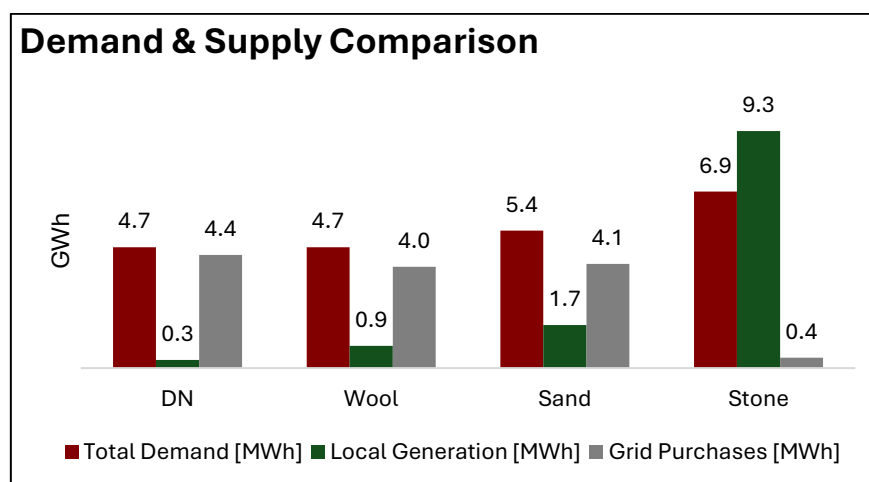


Figure 4.34. Demand and supply comparison

Figure 4.34. illustrates the increase in total demand across scenarios, alongside the rise in local generation and the corresponding decline in grid purchases. It can be observed that a continuous increase in total demand, combined with greater local generation, leads to a reduction in grid dependence. For this reason, even in scenarios with high total demand—such as the Stone scenario—if local generation is relatively equivalent, grid dependence can be as low as 2%. This figure demonstrates the importance of proper energy generation expansion planning, since demand tends to grow with time, supply must always be considered and projected to meet the future demand in the most efficient, cost-effective, sustainable way possible.

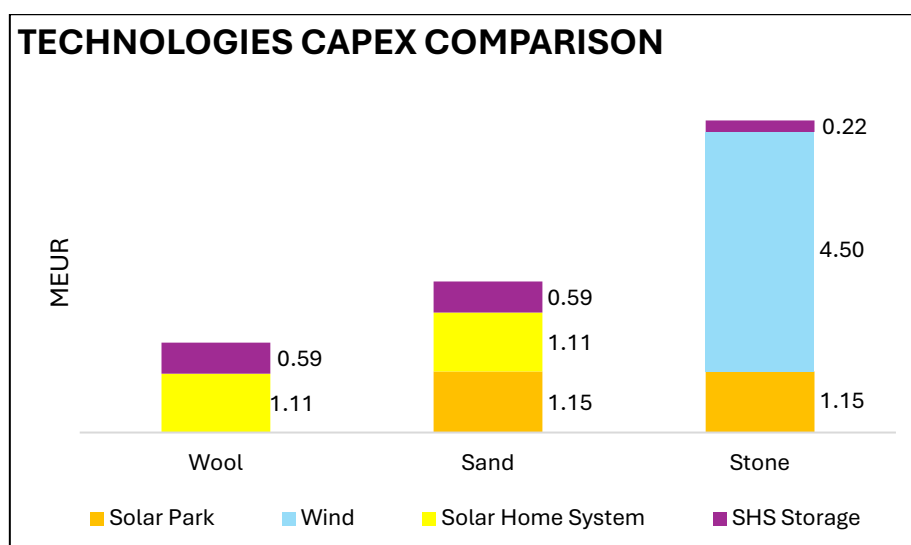


Figure 4.35. CAPEX comparison

As illustrated in Figure 4.35., while the CAPEX (initial investment) is zero in the DN scenario, scenario Wool sees a 1.7 million investment in solar home system, assuming all SHS system has a storage system. With an additional investment of 1.15 million euro in solar park, total CAPEX sums up to 2.85 million euro. In scenario Stone, investment in solar home system has been discouraged, and a community investment of 4.5 million euro in a wind turbine has been introduced; becoming the most independent scenario with a total CAPEX of 5.87 million euro.

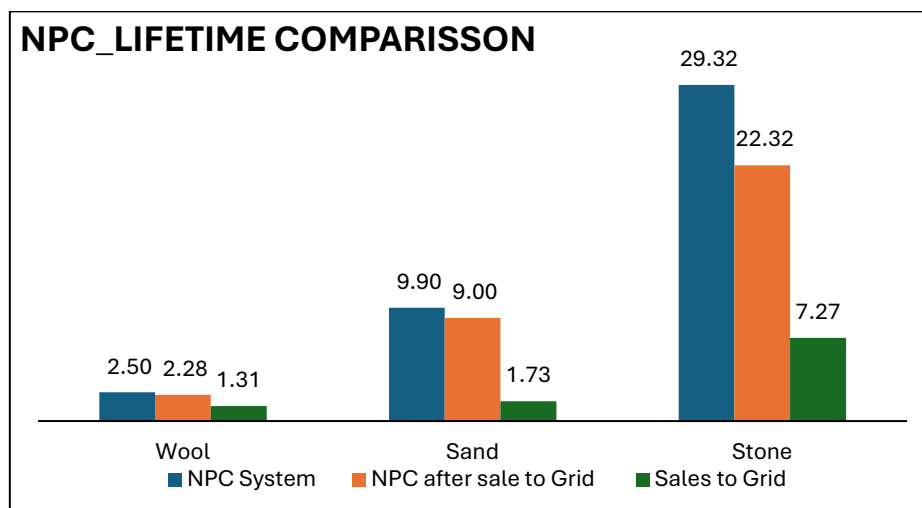


Figure 4.36. NPC lifetime comparison

Net present cost and NPC after sale to the grid for different scenarios are presented in the Figure 4.36. As it can be observed, the wool scenario sees a slight increase in both categories by investing in more rooftop PVs and home battery storage, respectively 1 MW and 1 MWh, raising the NPC to almost 2.5 million euro and around 2.3 million NPC after sale to the grid. In the sand scenario, additional investment in a 1 MW solar park increases the NPC to just below 10 million euro, while selling to the grid helps to reduce the financial burden and lowering NPC after sale to the grid to about 9 million euro. Finally, the stone scenario stands out as the costliest scenario with the NPC nearing 30 million euro by investing in a 1 MW solar park and a 2.3 MW wind turbine and adopting 100% electric cooking and heat pumps, housing retrofits and 100 EV and electric buses. However, after selling electricity to the grid, the NPC reduces noticeably to around 22.3 million euro.

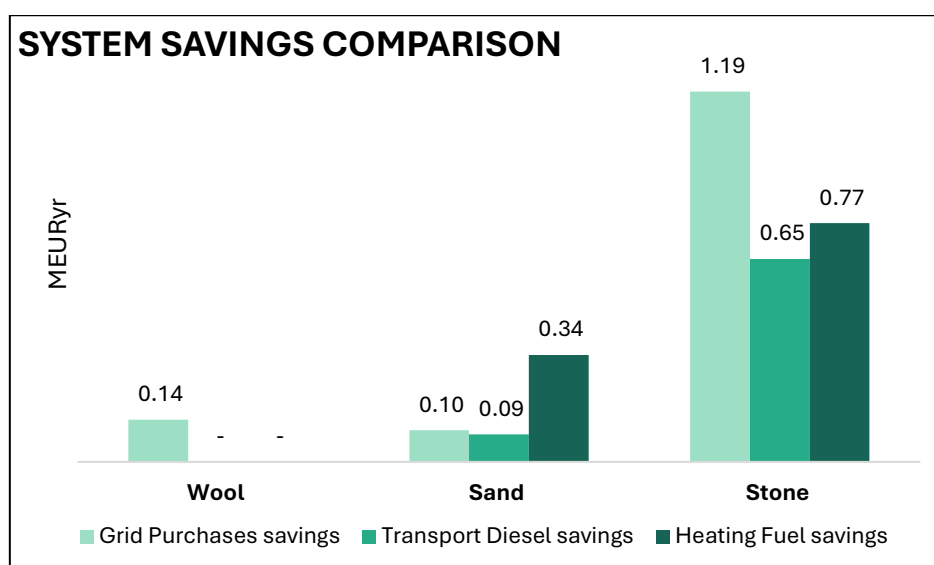


Figure 4.37. System savings comparison

Figure 4.37 highlights significant savings differences between Wool, Sand, and Stone across grid purchases, transport diesel, and heating fuel. In grid purchases, Stone achieves a 1,090% increase in savings over Sand and a 750% increase over Wool. Wool has higher grid savings than Sand, despite Sand having a lower percentage of grid purchases, because Sand's increased electricity demand resulted in higher total electricity usage, even though the system in Sand increased local generation. For transport diesel, Stone leads with a 622.2% increase over Sand, while Wool shows no savings. In heating fuel, Stone's savings are 126.5% higher than Sand's, with Wool again providing no savings. Overall, Stone delivers the highest savings across all categories, with a considerable increase compared to Sand and Wool, which show more modest or no savings.

The net savings data represent the annual NPC of the system, minus the savings from avoided purchases from the grid and fossil fuels. The resulting value is the net savings. In all three scenarios, the net savings are positive, demonstrating that the savings consistently exceed the system's annual NPC. Figure shows clear differences in financial performance between Wool, Sand, and Stone scenarios in Figure 4.38, when is compared to their system annual NPC. Wool results in a moderate net saving of 0.02 million euro, which is a 14% increase over its system costs. Sand performs better, with net savings of 0.08 million euro, representing a 17.8% increase over the system's annual NPC. However, Stone stands out significantly, achieving net savings of 1.50 million euro, which is a remarkable 36.4% increase over its system costs.

As the transition to renewable energy increases and fossil fuel use and purchases from the grid decreases, the net savings grow at an almost exponential rate. In other words, the more we shift towards renewables and reduce fossil fuel consumption and grid purchases, the greater the financial benefits become.

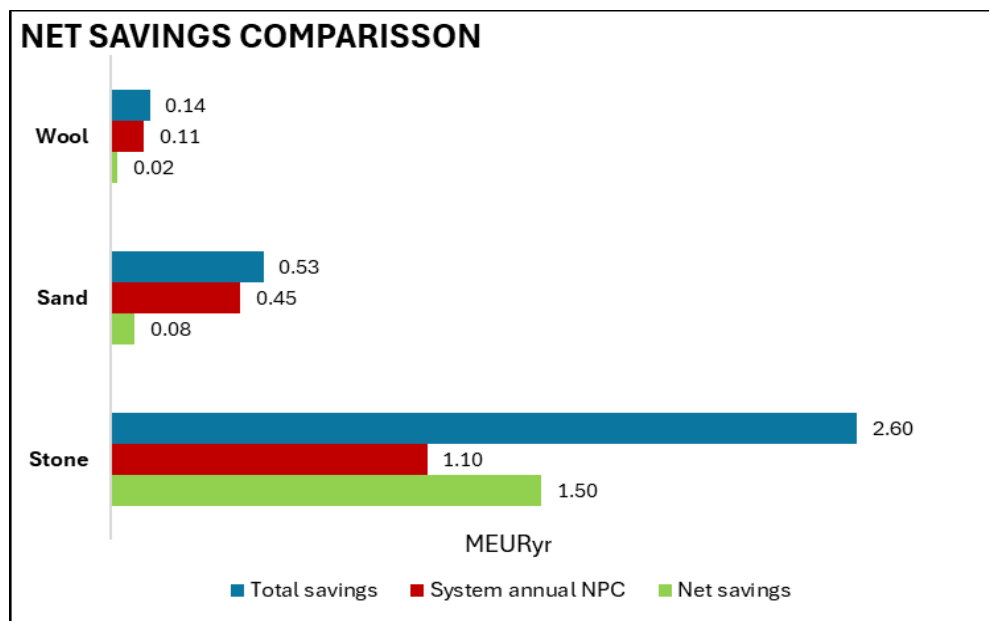


Figure 4.38. Net savings comparison

In the DN scenario, emission is the highest as the electricity purchase from grid is the maximum in this scenario, as evident in Figure 4.39. Wool scenario starts offsetting the island's carbon emission as the island starts selling electricity generated from RE sources back to the grid. The import emission is higher in Sand scenario, which is the result of the assumptions of higher demand, and thus higher purchase from the grid. However, as the generation from RE sources increases, the offset by exporting is also higher. The Aran island's net emission becomes negative

in the Stone scenario, with the lowest purchase from the grid and the most export of sustainable electricity, contributing the most to Ireland's net-zero goal by 2050.

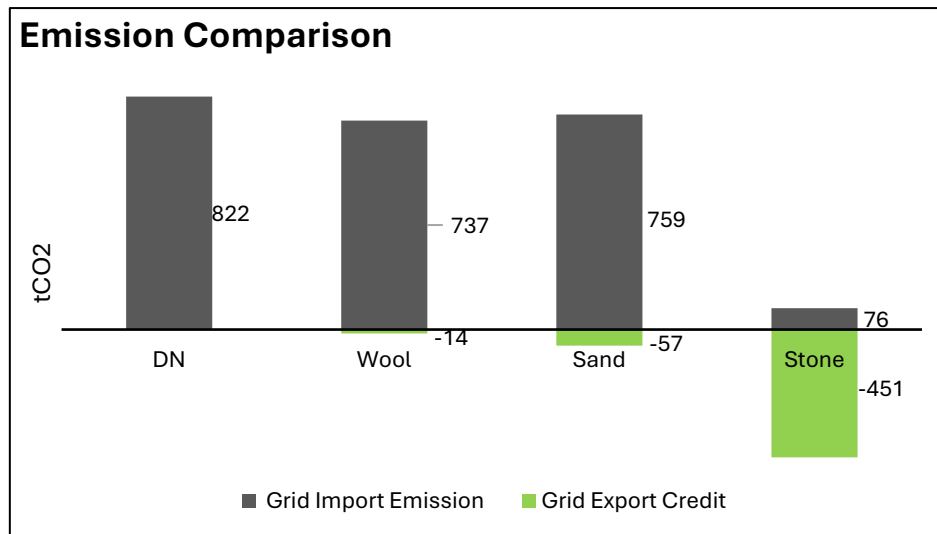


Figure 4.39. Emission comparison

4.6 Conclusion

This study explores three renewable energy scenarios for the island, each reflecting a different level of ambition: Wool (low), Sand (mid), and Stone (high). Wool relies primarily on SHS with minimal impact on grid dependence. Sand introduces a centralized PV park, reducing reliance on external power. Stone, the most ambitious, maximizes local generation adding a wind turbine generator, cutting grid dependence. By analysing these scenarios, this study provides a roadmap for decision-makers, outlining the technical, economic, and environmental trade-offs in the transition to energy independence.

The HOMER Pro simulations highlight that a diverse energy mix is key to a reliable and cost-efficient system. While centralized storage was found economically unfeasible, SHS with storage proved beneficial, enhancing individual energy independence and reducing overall grid demand. System flexibility improved significantly with local generation, reducing grid dependency from 93% in the Do-Nothing scenario to 4% in Stone.

Diversification of the generation mix plays a crucial role, particularly for an island aiming for energy resilience. The Sand scenario reduced grid purchases by 11% compared to Wool, demonstrating the impact of adding new technologies. However, meeting total demand solely with PV is unfeasible, emphasizing the need for a broader mix. Additionally, grid export limitations (650 kW) led to curtailment—3.2% in Sand and 4.0% in Stone.

Beyond energy security, each scenario directly impacts carbon emissions reduction. Wool achieved 285.1 tCO₂ savings, while Stone cut emissions by 1,192.9 tCO₂, reinforcing the environmental benefits of increased renewable adoption.

The financial analysis confirms the economic viability of renewable energy investments. All scenarios generate net savings, with Stone proving the most profitable at 1.50 million euro (36.4% over system costs), followed by Sand with 0.08 million euro (17.8%) and Wool with 0.02 million euro (14%). These findings strengthen the case for prioritizing local renewables, demonstrating their long-term economic and environmental benefits over continued grid dependence.

5 References

- Aalborg University. (2020). *EnergyPLAN Advanced energy system analysis computer model*. <https://Energyplan.Eu/about-Energyplan/>.
- Abdullah, D. (2024). *Wind farm site selection using GIS-based multicriteria analysis with Life cycle assessment integration*. <https://link.springer.com/article/10.1007/s12145-024-01227-4>
- Alamgeer, M. (2021). *Resource Assessment of Wind Energy Potential of Mokha in Yemen with Weibull Speed*. <https://doi.org/10.32604/cmc.2021.018427>
- Aran Islands Energy Co-op. (2025). *About/ History*. <https://www.aranislandsenergycoop.ie/contact-us/>
- Aran Islands energy co-operative. (2018). *Energy Master Plan 2018 Árainn and Inis Meáin*. <https://aranislandsenergycoop.ie/wp-content/uploads/2021/06/Energy-Masterplan.pdf>
- Aran Islands energy co-operative. (2024). *Energy Demand 2023*.
- Azizi, A. (2014). *Land suitability assessment for wind power plant site selection using ANP-DEMATEL in a GIS environment: case study of Ardabil province, Iran*. <https://doi.org/10.1007/s10661-014-3883-6>
- Baringa. (2018). *A 70% Renewable Electricity Vision for Ireland in 2030*. https://windenergyireland.com/images/Article_files/Final_Baringa_70by30_Report_web.pdf
- Bord Gáis. (2025). *Compare electricity price plans for your home*. <https://www.bordgaisenergy.ie/Home/Compare-Electricity-Price-Plans>.
- Caceoğlu, E., Yildiz, H. K., Oğuz, E., Huvaj, N., & Guerrero, J. M. (2022). Offshore wind power plant site selection using Analytical Hierarchy Process for Northwest Turkey. *Ocean Engineering*, 252, 111178. <https://doi.org/https://doi.org/10.1016/j.oceaneng.2022.111178>
- Carzone. (2025). *Used commercials for sale in Ireland | Carzone*. <https://www.carzone.ie/commercials/search?fuelType=Electric>
- CDC. (2025). *Controlling Legionella in Potable Water Systems*. <https://www.Cdc.Gov/Control-Legionella/Php/Toolkit/Potable-Water-Systems-Module.Html>.
- Central Statistics Office. (2022a). *CNA17: Population by Off Shore Island, Sex and Year*. <https://data.cso.ie/>
- Central Statistics Office. (2022b). *CNA17: Population by Off Shore Island, Sex and Year*. <https://data.cso.ie/>
- Centre for Sustainable Energy. (2025). *What is retrofit?* <https://www.cse.org.uk/news/what-is-retrofit/>
- Christian Pleijel. (2015). *Energy audit on the Aran Islands*. <https://europeansmallislands.com/wp-content/uploads/2013/01/aran.pdf>

- Clean Energy For EU Islands. (2019). *Clean Energy Transition Agenda*.
https://www.aranislandsenergycoop.ie/wp-content/uploads/2020/01/ARAN_FinalTransitionAgenda_20191118.pdf
- Clean Energy for EU Islands. (2019). *Clean Energy Transition Agenda Aran islands*.
- Cody, B., Loeschnig, W., & Eberl, A. (2018). Operating energy demand of various residential building typologies in different European climates. *Smart and Sustainable Built Environment*, 7(3–4), 226–250. <https://doi.org/10.1108/SASBE-08-2017-0035>
- Collins, N. (2021). *How extreme cold can crack lithium-ion battery materials, degrading performance*.
- CorPower. (2025a, February 21). *CorPower Ocean announces wave energy breakthrough*. https://Corpowerocean.Com/Corpower-Ocean-Announces-Wave-Energy-Breakthrough/?Utm_source=chatgpt.Com.
- CorPower. (2025b, February 21). *Projects*. <https://Corpowerocean.Com/Projects/>.
- Corpower Ocean. (2023). *ESB to join Simply Blue Group as partner on Saoirse Wave Energy project*. <https://Corpowerocean.Com/Esb-to-Join-Simply-Blue-Group-as-Partner-on-Saoirse-Project/>.
- CSO. (2022a). *Permanent private Households*. https://Ws.Cso.Ie/Public/Api.Restful/PxStat.Data.Cube_API.ReadDataset/SAP2022T6T5ED/XLSX/2007/En.
- CSO. (2022b). *Permanent private Households*. https://Ws.Cso.Ie/Public/Api.Restful/PxStat.Data.Cube_API.ReadDataset/SAP2022T6T5ED/XLSX/2007/En.
- Curtis, T., Heath, G., Walker, A., Desai, J., Settle, E., & Barbosa, C. (2021). *Best Practices at the End of the Photovoltaic System Performance Period*. <https://www.nrel.gov/docs/fy21osti/78678.pdf>.
- Danish Energy Agency. (2023). *Technology descriptions and projections for long-term energy system planning: Commercial freight and passenger transport*. <https://ens.dk/technologydata>
- Data Cellar. (2025). *CFOAT: Empowering the Aran Islands rural community with DATA CELLAR*. Data Cellar. <https://datacellarproject.eu/cases/cfoat-aran-islands/>
- DECC. (2021). *Climate Action Plan 2021*.
- Denny, E., & Keane, A. (2012). Munich Personal RePEc Archive A smart integrated network for an offshore island A Smart Integrated Network for an Offshore Island. In *30 UTC AUTHOR'S PRE-PRINT FOR SPECIAL ISSUE ON MARINE ENERGY AND ENVIRONMENTS IN THE PROCEEDINGS OF IEEE* (Vol. 15, Issue 43316).
- Department of Culture, H. and the G. (2019). *The Status of EU Protected Habitats and Species in Ireland*. https://www.npws.ie/sites/default/files/publications/pdf/NPWS_2019_Vol1_Summary_Article17.pdf

- Department of the Environment, C. & C. Irelandgov. ie. (2022). *Micro-generation Support Scheme (MSS) Final Scheme Design*.
- Department of the Environment, C. and C. (2025, February). *Small-Scale Renewable Electricity Generation*. https://www.gov.ie/en/publication/96110-small-scale-generation/?utm_source=chatgpt.com
- DoneDeal. (2025). *electric vehicle | 21 Ads in Coaches & Buses For Sale in Ireland | DoneDeal*. <https://www.donedeal.ie/coaches?words=electric%20vehicle>
- DOPE. (2025, February 21). *Project Evaluation/Appraisal: Applicable Rates*. <https://Www.Gov.Ie/En/Policy-Information/1a0dcb-Project-Discount-Inflation-Rates/>.
- Electric Ireland. (2025). *Electric Ireland Smart Meter Plans: Home Electric+*. <https://Www.Electricireland.Ie/Residential/Products/Smart-Meters/Plans>.
- Enercon. (n.d.-a). *Enercon E-82 EP2 E4 Technical Specs*. Retrieved February 25, 2025, from https://cdn.prod.website-files.com/64c38ca9b1a2e59bd5b7d64a/656a178801f71b16b0045a38_ENERCON%20E-82%20EP2%20E4%20en.pdf
- Enercon. (n.d.-b). *ENERCON offices*.
- Energy Master Plan 2018 *Árainn and Inis Meáin*. (2018).
- Energy Saving Trust. (2024). *Used electric vehicle loan - Energy Saving Trust*. <https://energysavingtrust.org.uk/grants-and-loans/used-electric-vehicle-loan/>
- ESA. (2020a). *World Land Cover*.
- ESA. (2020b). *World Land Cover*. <https://Worldcover2020.Esa.Int/Download>. <https://worldcover2020.esa.int/download>
- ESB Networks. (2022). Aran Island Grid Network. In *ESB Networks*.
- ESRI. (n.d.). *Understanding Euclidean distance analysis*. Retrieved January 20, 2025, from <https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/understanding-euclidean-distance-analysis.htm>
- European Comission. (2020). *State Aid SA.54683 (2020/N) – Ireland Renewable Electricity Support Scheme (RESS)* . <https://www.gov.ie/pdf/?file=https://assets.gov.ie/232782/9a0e8b7f-c7a9-4282-aebc-37316bb37d44.pdf#page=null>
- European Comission. (2025). *What is the Innovation Fund?* https://climate.ec.europa.eu/eu-action/eu-funding-climate-action/innovation-fund/what-innovation-fund_en
- European Commission. (2024). *saoires project*.
- EV Database. (2015). *Nissan Leaf (2018-2022) price and specifications*. <https://ev-database.org/car/1106/Nissan-Leaf>
- Ev Specifications. (2025). <https://Www.Evspecs.Org/>. <https://www.evspecs.org/tech-specs/nissan/leaf/40-kwh>

- Ford. (2025). *Ford E-Transit: The Electric Van For Your Business* | Ford IE.
<https://www.ford.ie/commercial-vehicles/e-transit>
- Galtech Energy Services. (n.d.). *Shadow Flicker*. Retrieved January 20, 2025, from
<https://www.pleanala.ie/publicaccess/EIAR-NIS/308448/2.%20EIAR/Volume%20III/Chapter%2011%20Shadow%20Flicker.pdf>
- Gary, D. (2023). *The Power of Economies of Scale: A Wind Industry Case Study*.
<https://doi.org/https://doi.org/10.13052/spee1048-5236.4234>
- Global Solar Atlas. (2024). *Maps*. <https://Globalsolaratlas.info/Download>.
- Global Wind Atlas. (2024). *Power Density*.
- Goodhew, J., Pahl, S., Auburn, T., & Goodhew, S. (2015). Making Heat Visible: Promoting Energy Conservation Behaviors Through Thermal Imaging. *Environment and Behavior*, 47(10), 1059. <https://doi.org/10.1177/0013916514546218>
- Government of Ireland. (2023). *Improving Energy Efficiency in Traditional Buildings: Guidance for Specifiers and Installers*.
- Halpin, B. (2024). *Navigating Ireland's Fluctuating Electricity Market: Impact on Household Bills*.
<https://www.weswitchu.ie/blog-news/post/electricity-pricing-ireland/>.
- Herrando, M., Cambra, D., Navarro, M., de la Cruz, L., Millán, G., & Zabalza, I. (2016). Energy Performance Certification of Faculty Buildings in Spain: The gap between estimated and real energy consumption. *Energy Conversion and Management*, 125, 141–153.
<https://doi.org/10.1016/j.enconman.2016.04.037>
- Hopper, J., Littlewood, J. R., Taylor, T., Counsell, J. A. M., Thomas, A. M., Karani, G., Geens, A., & Evans, N. I. (2012). Assessing retrofitted external wall insulation using infrared thermography. *Structural Survey*, 30(3), 245–266.
<https://doi.org/10.1108/02630801211241810>
- HORGAN, T. (2020). Selkie-Ocean Energy GIS-TE Platform. In
https://rossoconnell.github.io/Selkie_Techno_Economic_GIS/. MaREI, The SFI Research Centre for Energy Climate and Marine Beaufort Building University College Cork
 Haulbowline Road Ringaskiddy Co. Cork P43 C573.
- Hubbard, C. J. (2019). *LDV EV80 large electric van review*. <https://www.parkers.co.uk/vans-pickups/news/2017/ldv-ev80-large-electric-van-review/>
- IEA. (2025). *Electricity 2025*. www.iea.org
- Inishbofin Development Company DLC. (2022). *Inishbofin Energy Transition Plan*.
<https://inishbofin.com/wp-content/uploads/2022/02/Inishbofin-Energy-Transition-Plan-2022.pdf>
- Ireland Central Statistics Office. (2021). *Electric Vehicles Sustainable Mobility and Transport 2021 - Central Statistics Office*. <https://www.cso.ie/en/releasesandpublications/ep/p-smt/sustainablemobilityandtransport2021/electricvehicles/>
- Irish Department of Transport. (2023). *National Road Network EV Charging Plan 2024-2030*.
- J. Rivas, M., Stanley, J., & Forkan, G. (2018a). *Energy Master Plan 2018 Árainn and Inis Meáin*.

- J. Rivas, M., Stanley, J., & Forkan, G. (2018b). *Energy Master Plan 2018 Árinn and Inis Meáin*.
- J. Rivas, M., Stanley, J., & Forkan, G. (2018c). *Energy Master Plan 2018 Árinn and Inis Meáin*.
- Jahangir, M. H., Alimohamadi, R., & Montazeri, M. (2023). Performance comparison of pelamis, wavestar, langley, oscillating water column and Aqua Buoy wave energy converters supplying islands energy demands. *Energy Reports*, 9, 5111–5124.
<https://doi.org/10.1016/j.egyr.2023.04.051>
- James Wilson. (2023). The COVID-19 pandemic led to a “baby boom” boosted the population of one of the Aran Islands. . *Newstalk.Com*. <https://www.newstalk.com/news/covid-baby-boom-boosted-population-of-aran-island-1480840>
- Lampeter, R. (2011). *Shadow Flicker Regulations and Guidance: New England and Beyond*.
https://windexchange.energy.gov/files/pdfs/workshops/2011/webinar_shadow_flicker_lampeter.pdf
- LM Wind Power. (n.d.). *What is Wind Class*. Retrieved January 20, 2025, from
<https://www.lmwindpower.com/en/stories-and-press/stories/learn-about-wind/what-is-a-wind-class>
- Macrotrends. (2025). *Ireland Inflation Rate 1960-2025*. <https://www.Macrotrends.Net/Global-Metrics/Countries/IRL/World/Inflation-Rate-Cpi>.
- Malachy Walsh and Partners. (2020). *Shadow Flicker*. <https://carrownagowanplanning.ie/wp-content/uploads/2020/12/Chapter%2011%20Shadow%20Flicker.pdf>
- Maoildhia, D. Ó. (2022). *Meeting of the Joint Committee on Social Protection, Community and Rural Development and the Islands*.
- Michel. (2024). *Wind farm site selection using GIS-based mathematical modeling and fuzzy logic tools: a case study of Burundi*. <https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2024.1353388/full>
- Name1, F., Name2, F., & Name3, F. (2025). Sample Reference. *International Class*, 1(1), 1–2.
- National Aerospace Laboratory NLR. (2011). *Wind turbine noise: primary noise sources*.
<https://reports.nlr.nl/server/api/core/bitstreams/9de8dfe0-5ab7-4c3e-ae9-1e0dfdbce766/content>
- National Monuments Service. (n.d.). *Archeological Survey of Ireland*.
- National Parks and Wildlife Service. (2024). *National Parks and Wildlife Service*.
<https://Experience.Arcgis.Com/Experience/Edf34d92e28040fd87d3d14f55d8d95f/Page/Page/>.
- National Parks and Wildlife Services. (2019). *National Parks and Wildlife Services*.
<https://Experience.Arcgis.Com/Experience/Edf34d92e28040fd87d3d14f55d8d95f/Page/Page/>.
- National Parks and Wildlife Services. (2024). *National Parks and Wildlife Services*.
<https://Experience.Arcgis.Com/Experience/Edf34d92e28040fd87d3d14f55d8d95f/Page/Page/>.

- NEOCyce GmbH & Co. KG. (2023). *Insel Inishmaan - Demontage 2 x Vestas V27*.
<https://neocyce.com/case-studies/inishmaan/>
- New European Wind Atlas. (2019). *New European Wind Atlas*. Database.
<https://map.neweuropeanwindatlas.eu/>
- Noorollahi, E., Fadai, D., Shirazi, M. A., & Ghodsipour, S. H. (2016). Land suitability analysis for solar farms exploitation using GIS and fuzzy analytic hierarchy process (FAHP) - A case study of Iran. *Energies*, 9(8). <https://doi.org/10.3390/en9080643>
- Nouvel, R., Zirak, M., Coors, V., & Eicker, U. (2017). The influence of data quality on urban heating demand modeling using 3D city models. *Computers, Environment and Urban Systems*, 64, 68–80. <https://doi.org/10.1016/j.compenvurbsys.2016.12.005>
- NREL. (2024). *Commercial Battery Storage*. NREL.
https://atb.nrel.gov/electricity/2024/commercial_battery_storage
- O’Connell, R., Furlong, R., Guerrini, M., Cullinane, M., & Murphy, J. (2023). Development and Application of a GIS for Identifying Areas for Ocean Energy Deployment in Irish and Western UK Waters. *Journal of Marine Science and Engineering*, 11(4).
<https://doi.org/10.3390/jmse11040826>
- Open Street Map. (2024a). *Buildings*.
- Open Street Map. (2024b). *Open Street Map*. <https://www.openstreetmap.ie/>.
- Papadopoulos, A. M. (2005). State of the art in thermal insulation materials and aims for future developments. *Energy and Buildings*, 37(1), 77–86.
<https://doi.org/10.1016/j.enbuild.2004.05.006>
- Patil, A. A., Arora, R., Arora, R., & Sridhara, S. N. (2023). Performance Analysis of Hybrid Renewable Energy Using Homer Software. In *Tuijin Jishu/Journal of Propulsion Technology* (Vol. 44, Issue 3).
- Pennock, S., Vanegas-Cantarero, M. M., Bloise-Thomaz, T., Jeffrey, H., & Dickson, M. J. (2022). Life cycle assessment of a point-absorber wave energy array. *Renewable Energy*, 190, 1078–1088. <https://doi.org/10.1016/j.renene.2022.04.010>
- Piirisaar, I. (n.d.). *A multi-criteria GIS analysis for siting of utility-scale photovoltaic solar plants in county Kilkenny, Ireland*.
- Rawat, A., Monteiro, B., Ahadzi, D., Eustinah, F., Sithole, T., Taha, H., Maharani, I. N., Alfiana, D., Bahmani, M., Mansouri, M., Mendoza, P., Chhipa, R., Lopez, S., Mohammed, S., Taha, S., & Siddiqui, A. (2024). *Transition Pathways for Decarbonisation and Self Sufficiency on the Isle of Eigg: International Class 2024*.
- Renewables ninja. (2019). *Merra 5 Wind 96m height V27 turbine*.
<https://www.renewables.ninja/>
- Road Management Office. (2023). *Regional Road Networks*.
<https://Data.Gov.ie/Dataset/Regional-Road>.

- Schwela, D. (2001). *The new World Health Organization guidelines for community noise*. https://www.researchgate.net/publication/290621647_The_new_World_Health_Organization_guidelines_for_community_noise
- SEAI. (n.d.). *Conditional Planning*. Retrieved January 20, 2025, from https://www.seai.ie/sites/default/files/publications/Conditional_Planning_Exemptions.pdf
- SEAI. (2017). *Annual Report 2017 on Public Sector Energy Efficiency Performance*. https://www.seai.ie/sites/default/files/publications/2017_Annual_Report_on_Public_Sector_Energy_Efficiency_Performance.pdf
- SEAI. (2019). *Orla Coyle-NZEB and High Performance Retrofit-Programme Manager Tipperary NZEB Event Achieving NZEB-Dwellings*.
- SEAI. (2024a). *Charging an Electric Vehicle | Electric Vehicles | SEAI*. <https://www.seai.ie/plan-your-energy-journey/for-your-home/electric-vehicles/about-evs/ev-charging>
- SEAI. (2024b). *Community Energy Resource Toolkit The Planning Process*. <https://www.seai.ie/sites/default/files/publications/Community-Toolkit-Planning-Process.pdf>
- SEAI. (2024c). *Conversion Factors | SEAI Statistics | SEAI*. <https://www.seai.ie/Data-and-Insights/Seai-Statistics/Conversion-Factors>
- SEAI. (2024d). *Emission factors for electricity*. <https://www.seai.ie/Data-and-Insights/Seai-Statistics/Conversion-Factors>
- SEAI. (2024e). *Wind potential*. <https://experience.arcgis.com/experience/adeb20a08bdd477082a3975b3483cce6>
- SEAI. (2025). *Energy price trends*. SEAI. <https://www.seai.ie/data-and-insights/seai-statistics/prices>
- Smith, J. (2024). Major €100 cash blow for hard-hit households as electricity bills set to soar to help ‘support investment’ in network. *The Sun*.
- Solis. (2025). *Solis Single Phase Low Voltage Energy Storage Inverters*. www.solisinverters.com
- Staffell, I., Pfenninger, S., & Johnson, N. (2023). A global model of hourly space heating and cooling demand at multiple spatial scales. *Nature Energy*, 8(12), 1328–1344. <https://doi.org/10.1038/s41560-023-01341-5>
- Suna, D., Pardo Garcia, N., & Totschnig, G. (2020a, January). *AN ASSESSMENT OF 100% RENEWABLES IN ELECTRICITY AND HEAT IN ARAN ISLANDS BY 2030*.
- Suna, D., Pardo Garcia, N., & Totschnig, G. (2020b, January). *AN ASSESSMENT OF 100% RENEWABLES IN ELECTRICITY AND HEAT IN ARAN ISLANDS BY 2030*.
- Sunte, J. (2022). *The Design of 1 MW Solar Power Plant*. www.ijsrmme.com
- Sustainable Energy Authority of Ireland. (2024a). *BER Map*. <https://www.seai.ie/ber/support-for-ber-assessors/ber-assessment-data/ber-map>

- Sustainable Energy Authority of Ireland. (2024b). *Final Energy Consumption in Residential*. <https://www.seai.ie/data-and-insights/seai-statistics/annual-energy-data/energy-demand/residential>
- Sustainable Energy Authority of Ireland. (2024c). *Final Energy Consumption in Residential*. <https://www.seai.ie/data-and-insights/seai-statistics/annual-energy-data/energy-demand/residential>
- Sustainable Energy Authority of Ireland (SEAI). (2024). *Community grant project criteria and funding*. <https://www.seai.ie/grants/find-a-registered-professional/community-project-coordinator/project-criteria-and-funding>
- TABULA. (2014). *Building Typology Brochure Ireland*. www.building-typology.eu
- Technology descriptions and projections for long-term energy system planning. Commercial freight-and passenger transport*. (2023). <https://ens.dk/technologydata>
- Tellarini, C., & Gram-Hanssen, K. (2024). “If something breaks, who comes here to fix it?”: Island narratives on the energy transition in light of the concept of practice architectures. *Energy Research and Social Science*, 114. <https://doi.org/10.1016/j.erss.2024.103617>
- Tesla. (2025). *Tesla Megapack 2 XL*.
- TGS 4C offshore database. (2024). *Offshore Wind Farms in Ireland*. <https://www.4coffshore.com/windfarms/ireland/>
- The Status of EU Protected Habitats and Species in Ireland*. (2019).
- Tithe an Oireachtais Houses of the Oireachtas. (2022). *An Oifig Buiséid Pharlaiminteach Parliamentary Budget Office*.
- Tom. (2015). *Rooftop Wind Turbines: Are They Worthwhile?*
- Totally Dublin. (2023). *Solar Farm income per Acre in Ireland*. <https://www.Totallydublin.ie/More/Solar-Farm-Income-per-Acre-in-Ireland/>.
- Tractebel. (2024). *Workshop on sustainable approaches to wind turbine decommissioning*. https://www.interregeurope.eu/sites/default/files/2024-12/A3.3_Summary%20report_Sustainable%20approaches%20to%20wind%20turbine%20decommissioning%20.pdf
- Turner, M., Zhang, Y., & Rix, O. (2018). *Energy Vision 2030 Baringa Partners LLP is a Limited Liability Partnership registered in England and Wales with registration number OC303471 and with registered offices at 3rd Floor, Confidentiality and Limitation Statement*. <http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Tomorrows-Energy-Scenarios-Report-2017.pdf>
- USGS. (n.d.). *Data Elevation Model*. <https://Earthexplorer.Usgs.Gov/>.
- USGS. (2024). *Data Elevation Model*. <https://Earthexplorer.Usgs.Gov/>
<https://earthexplorer.usgs.gov/>
- USGS. (2025). *What is a digital elevation model?* <https://www.Usgs.Gov/Faqs/What-a-Digital-Elevation-Model-Dem>.

- Wang, Y. ; , Feng, Y.-H. ; , Fan, X.-Y. ; , Han, X. ; , Wang, P.-F., Bella, F., Luo, H., Wang, Y., Feng, Y.-H., Fan, X.-Y., Han, X., & Wang, P.-F. (2022). Lithium-Ion Batteries under Low-Temperature Environment: Challenges and Prospects. *Materials*, 15(22), 8166. <https://doi.org/10.3390/MA15228166>
- WeCo. (2025). *WeCo Dual Voltage 5K3-XP*.
- Whitten, L. C., & Robb, N. (2022). *The Single Electricity Market in Ireland and Northern Ireland*. <https://ukandeu.ac.uk/explainers/the-single-electricity-market-in-ireland-and-northern-ireland/>.
- Windsor. (2025). *Electric Cars & Hybrids | New & Used | Windsor Motors*. <https://www.windsor.ie/electric-hybrid/>
- Wiser, Ryan. Y. Zhenbin. (2014). *Noise, flicker, health and safety* . 2014. <https://www.wind-watch.org/documents/noise-flicker-health-and-safety/>
- World Bank. (2024). *Population, total - Ireland*. <https://data.worldbank.org/indicator/SP.POP.TOTL?locations=IE>
- Yang, Amr, Bahaa, & Reda. (2022). *A High-Resolution Wind Farms Suitability Mapping Using GIS and Fuzzy AHP Approach: A National-Level Case Study in Sudan*. <https://www.mdpi.com/2071-1050/14/1/358>
- Yu, J., Dong, Y., Wang, T. H., Chang, W. S., & Park, J. (2024). U-Values for Building Envelopes of Different Materials: A Review. In *Buildings* (Vol. 14, Issue 8). Multidisciplinary Digital Publishing Institute (MDPI). <https://doi.org/10.3390/buildings14082434>
- Zalhaf, A. S. (2021). *A High-Resolution Wind Farms Suitability Mapping Using GIS and Fuzzy AHP Approach: A National-Level Case Study in Sudan*. <https://doi.org/10.3390/su14010358>
- ZapMap. (2020). *Mercedes eSprinter EV charging guide - Zapmap*. <https://www.zap-map.com/ev-guides/model-charging/mercedes-benz-esprinter>

6 Appendices

6.1 Heating and retrofitting assessment

6.1.1 Status of home insulation

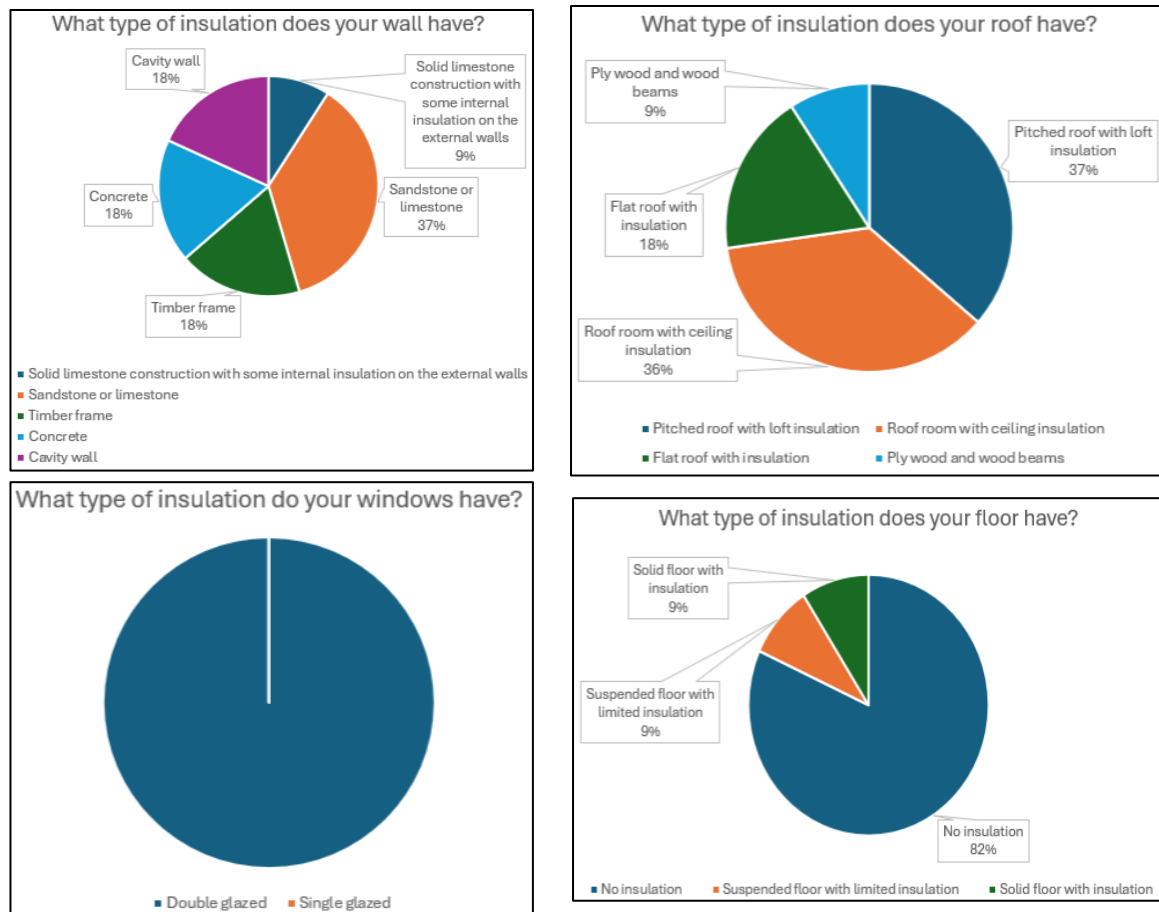
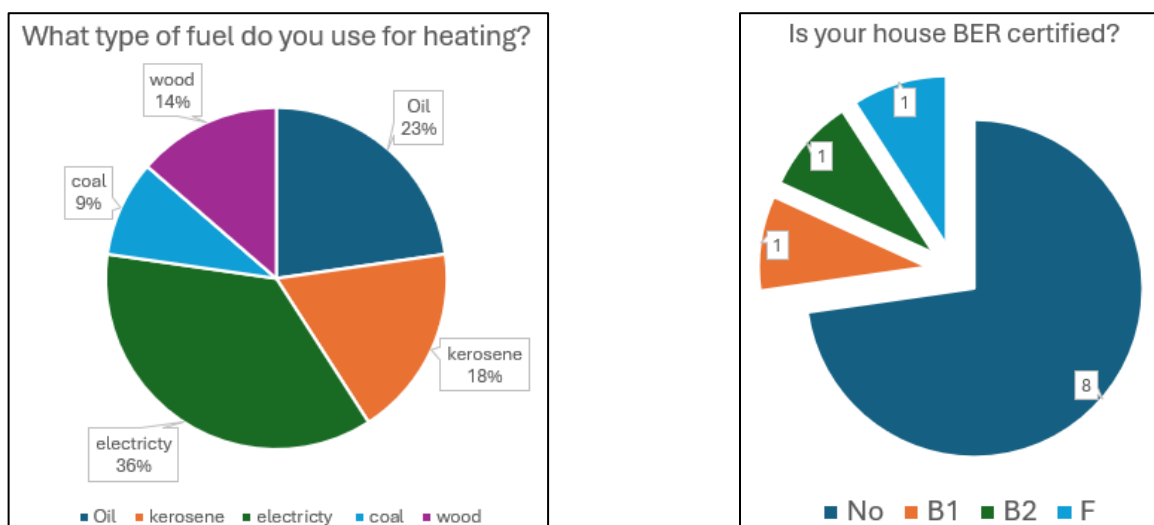


Figure 6.1. Online survey of home insulation results

6.1.2 Status of heating system



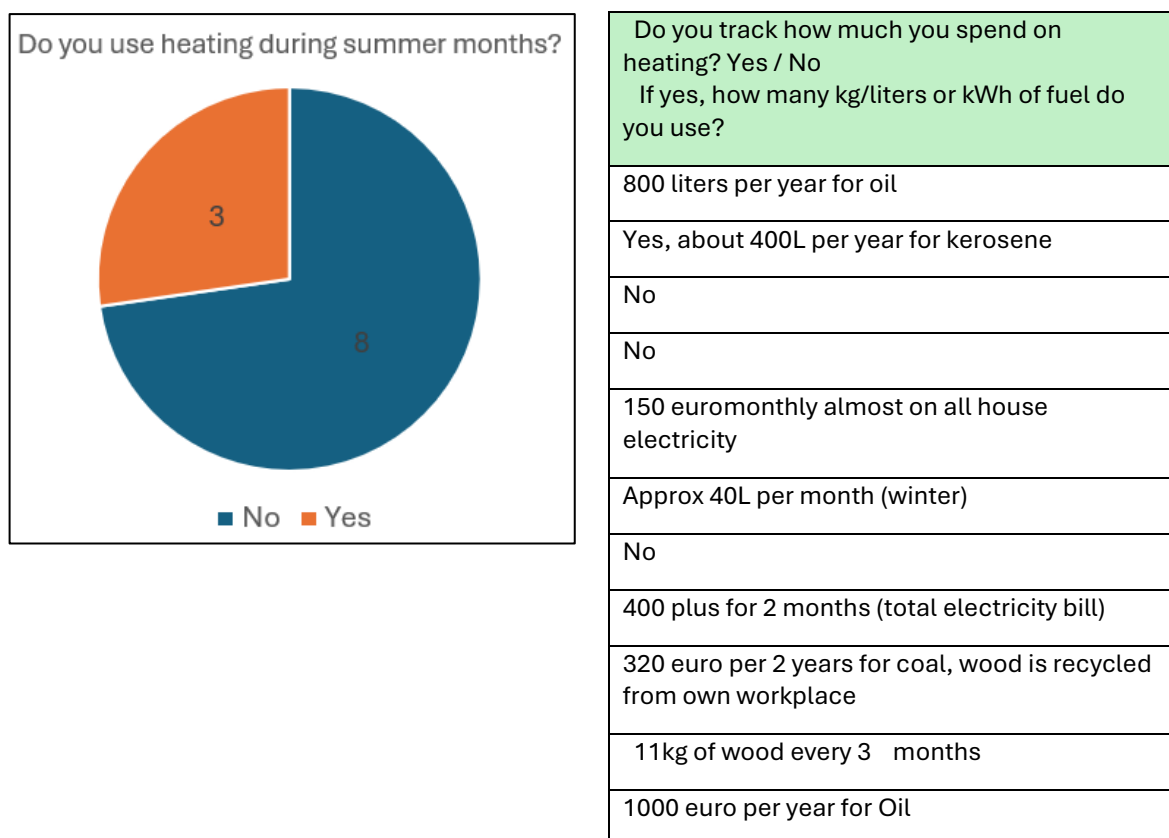


Figure 6.2. Online survey of heating status results

6.1.3 Opinion and willingness for transition

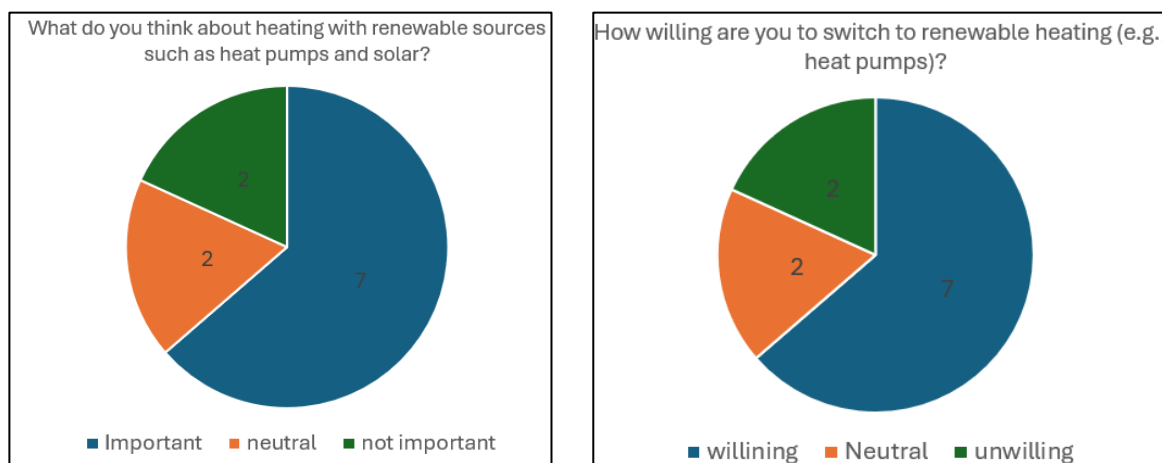


Figure 6.3. Online survey of willingness for transition results

6.1.4 Housing details

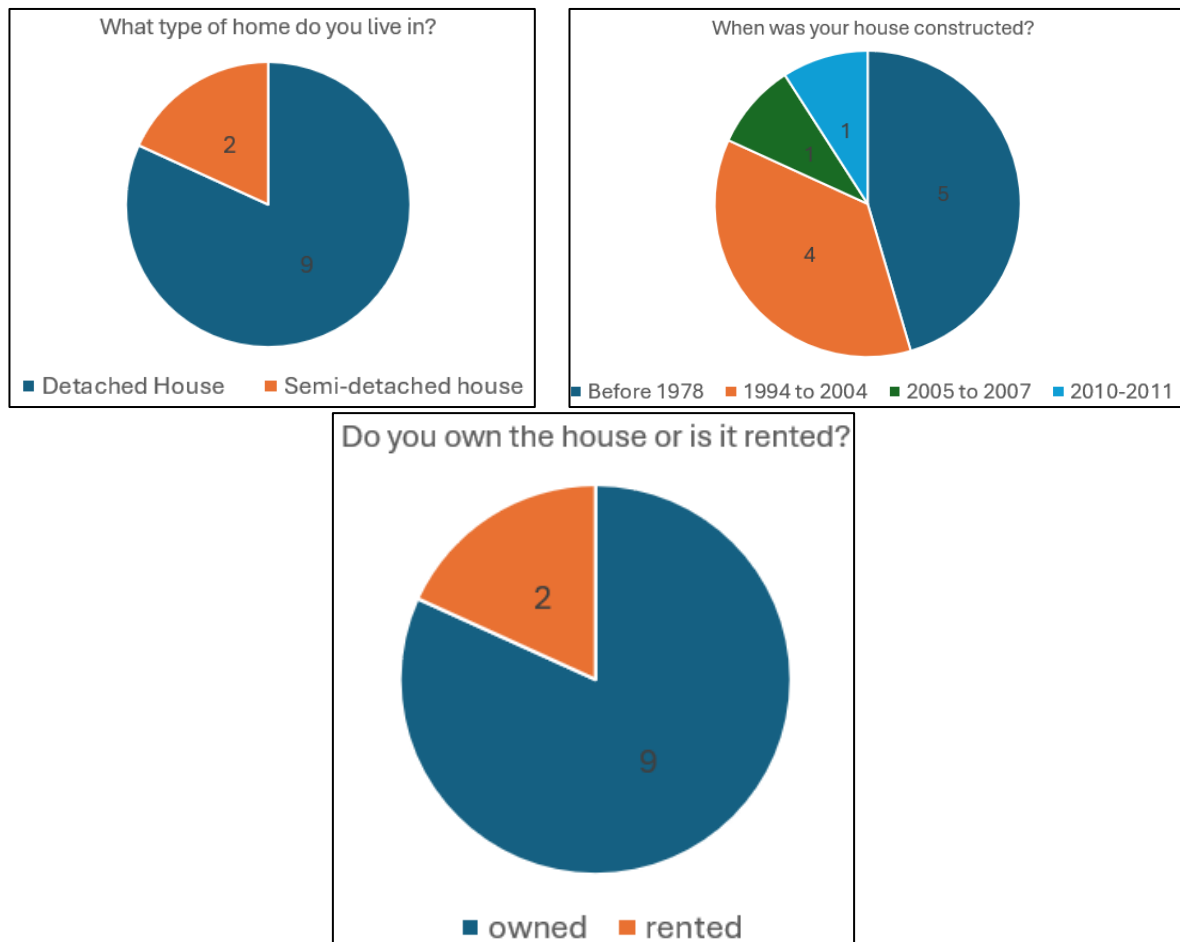


Figure 6.4. Online survey of housing details results

6.2 Renewable energy technologies assessment

6.2.1 General demand analysis

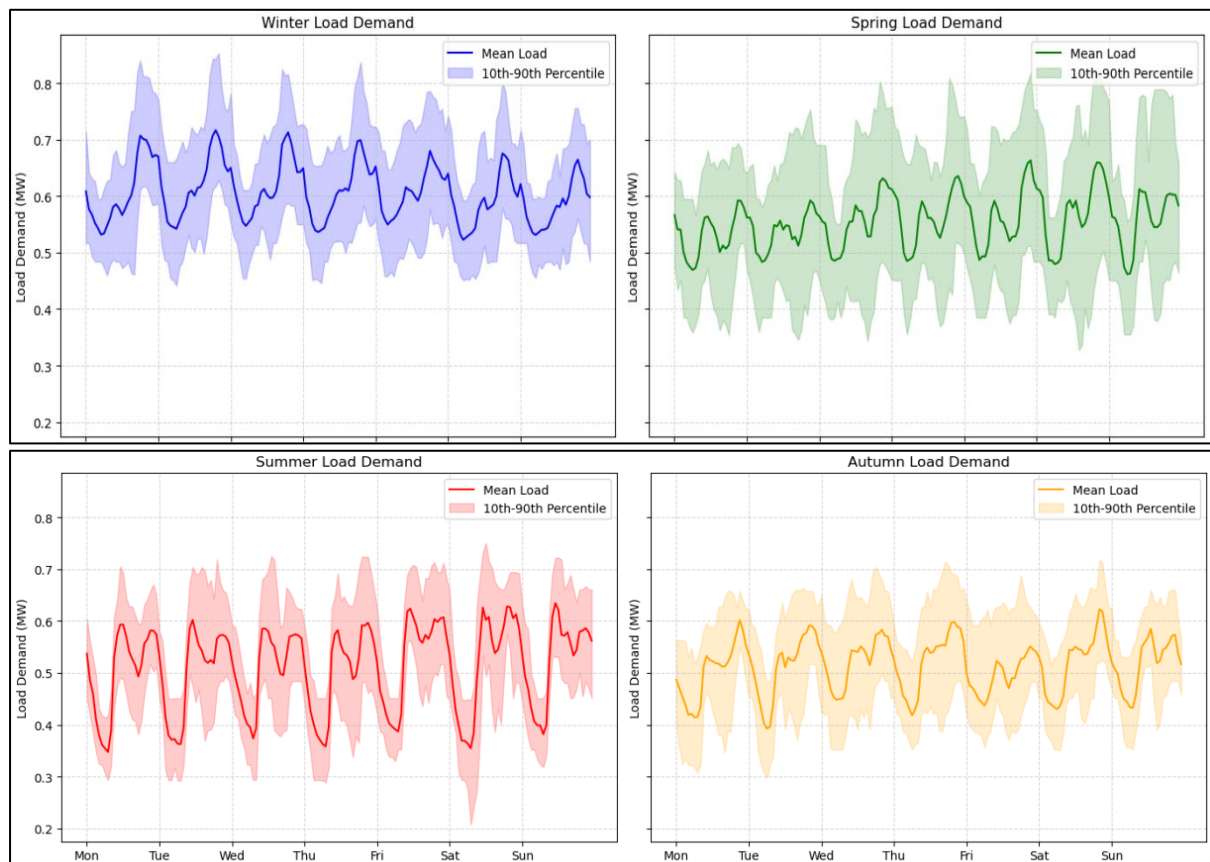


Figure 6.5. Seasonal load demand

6.2.2 Solar PV potential assessment

Table 6.1. Datasets used in the study

N ^o	Data	Source	Data Type
1	Global Horizontal Irradiation	(Global Solar Atlas, 2024)	Raster
2	Digital Elevation Model	(USGS, 2024)	File Geodatabase Raster
3	Landcover	(ESA, 2020b)	File Geodatabase Raster
4	Distance from Road Networks	(Road Management Office, 2023)	File Geodatabase Feature Class
5	Special Area of Conservation	(National Parks and Wildlife Services, 2024)	Shapefile Feature Class
6	Special Protection Area		Shapefile Feature Class
7	Natural Heritage Area	(National Parks and Wildlife Services, 2019)	Shapefile Feature Class
8	Buildings	(Open Street Map, 2024b)	File Geodatabase Feature Class
9	SMR Zone	(Open Street Map, 2024b)	File Geodatabase Feature Class

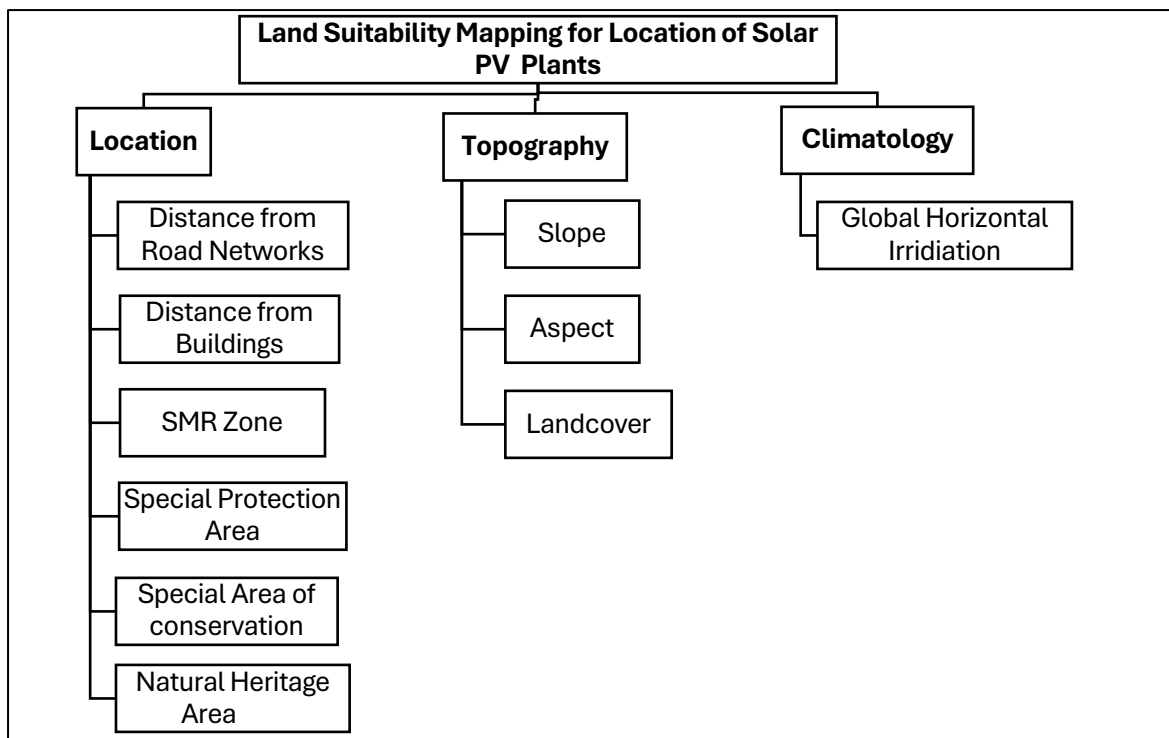


Figure 6.6. Selection criteria used for site suitability of solar PV in Aran Islands

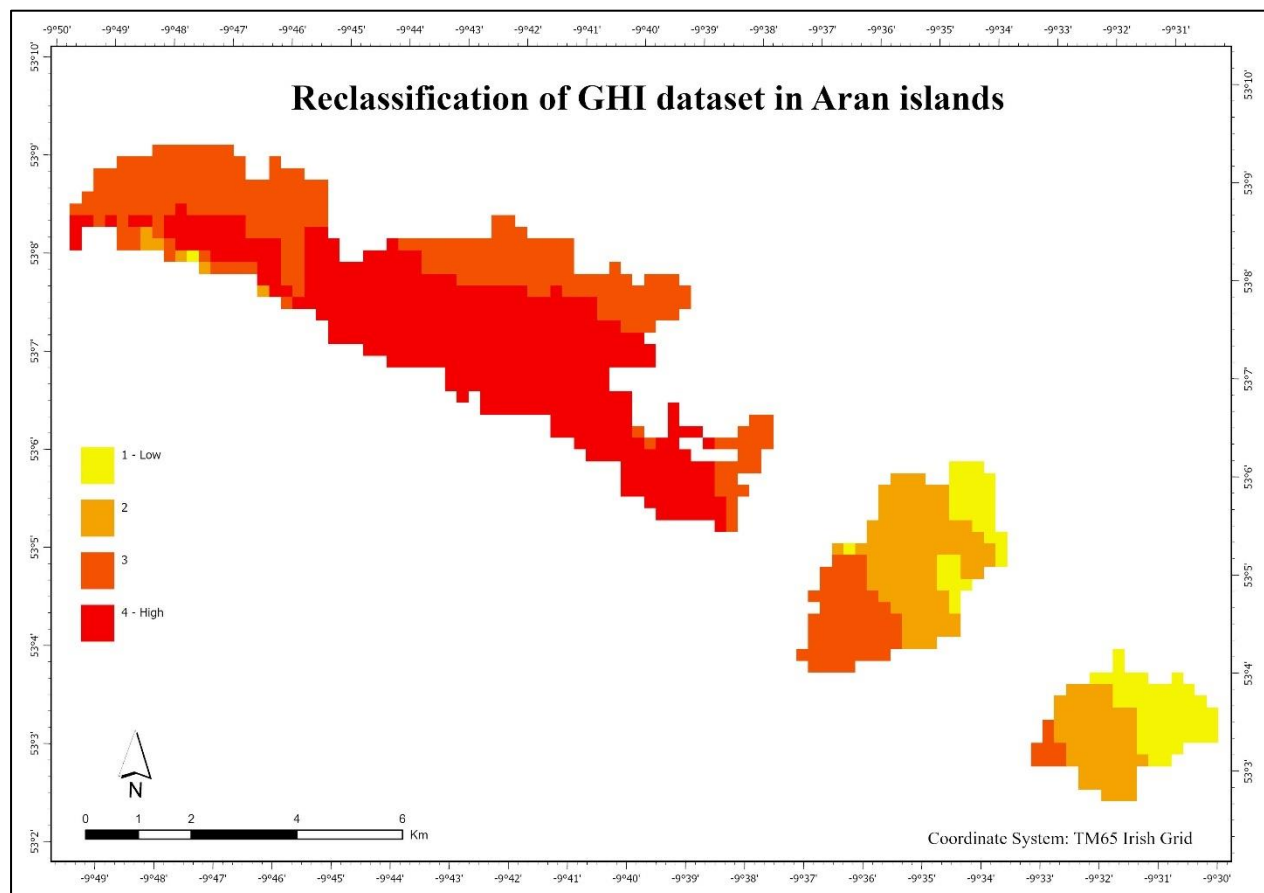


Figure 6.7. Reclassification of GHI dataset

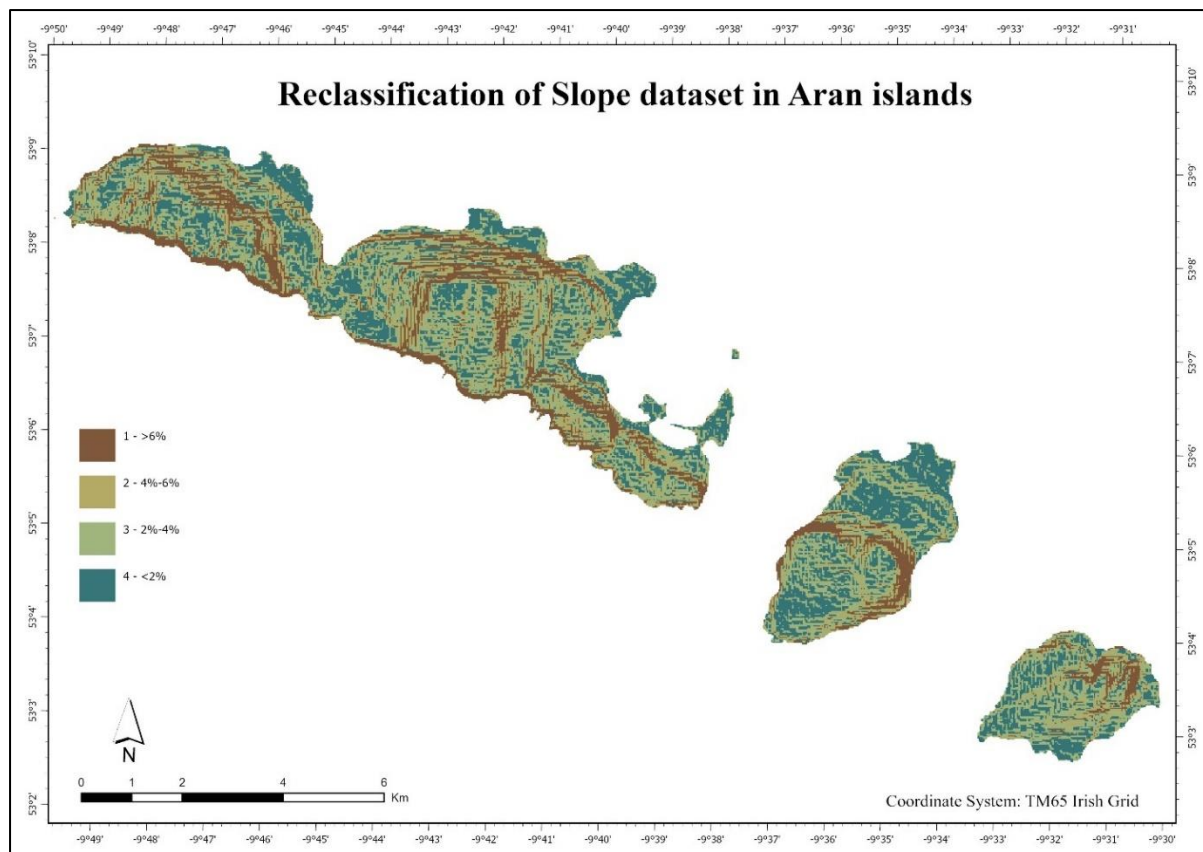


Figure 6.8. Reclassification of slope dataset

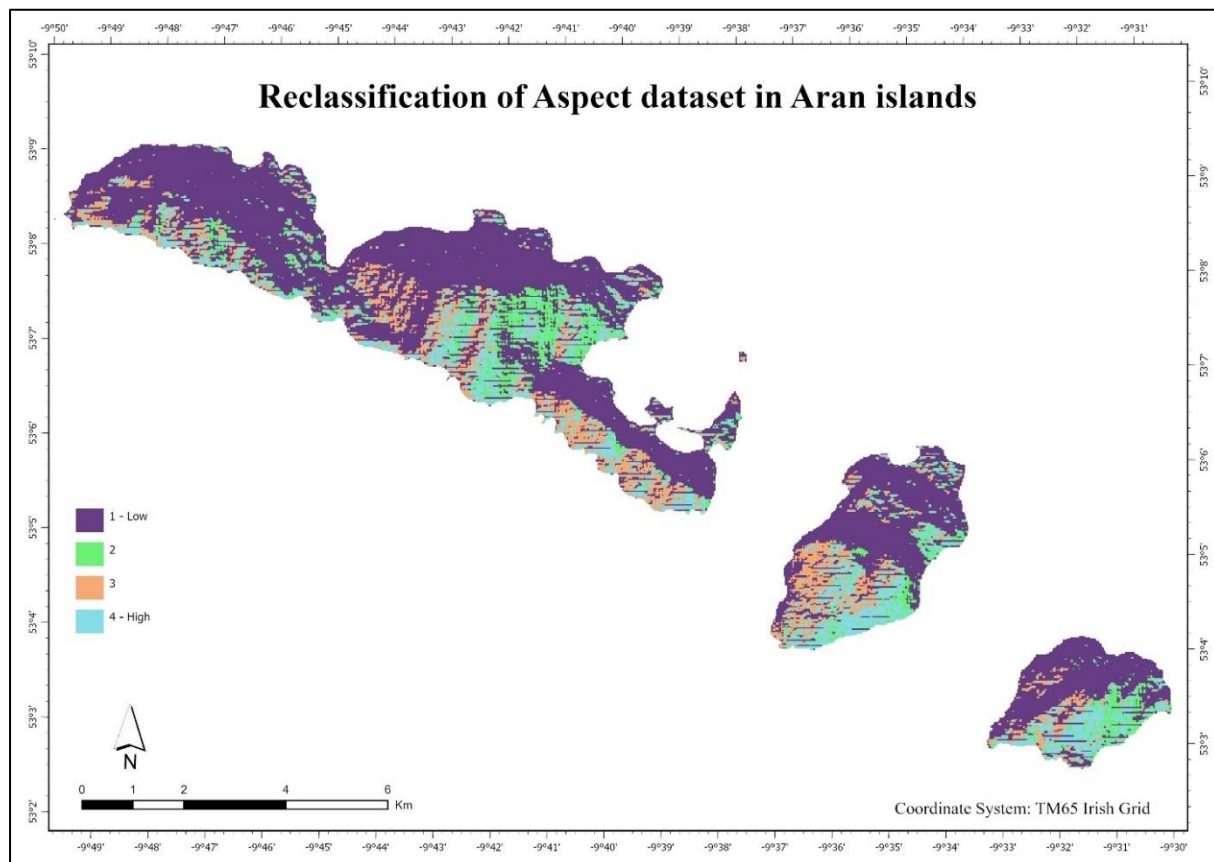


Figure 6.9. Reclassification of aspect dataset

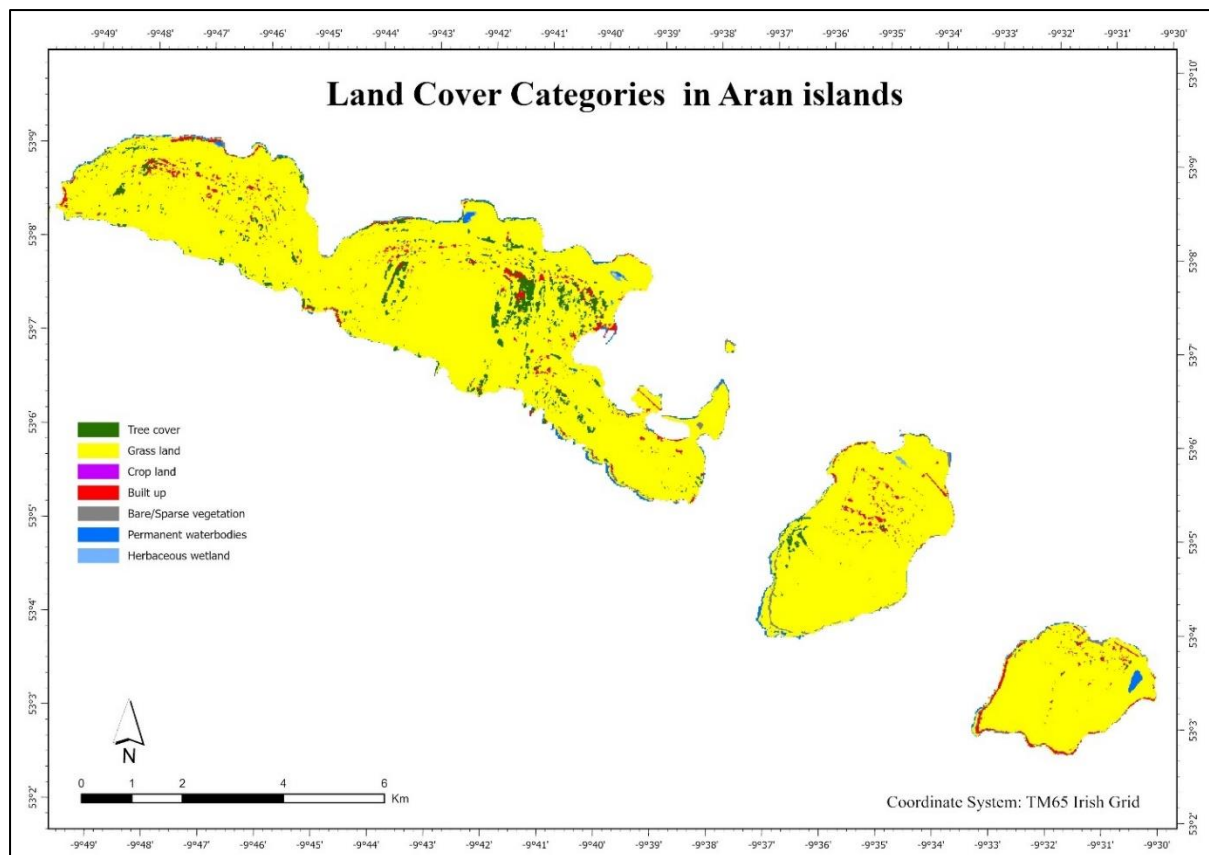


Figure 6.10. Landcover categories of the study area

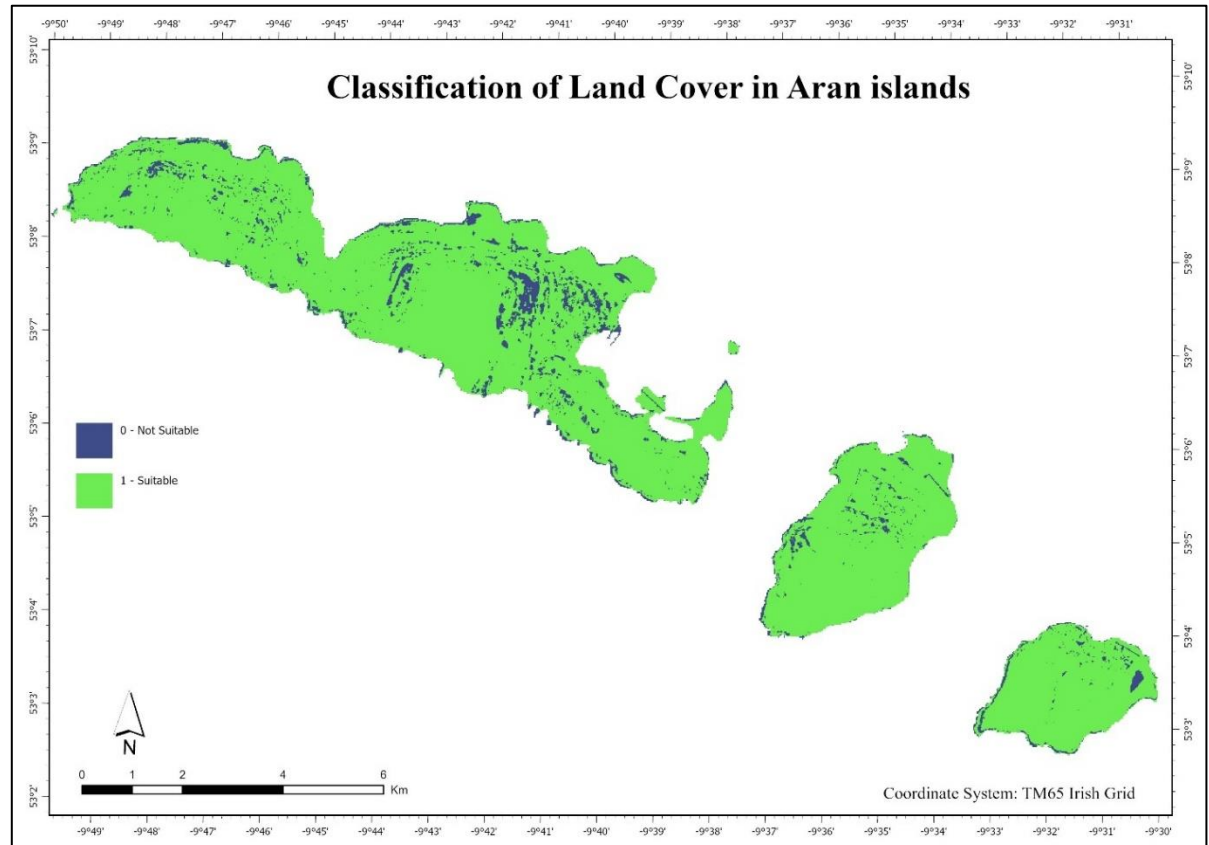


Figure 6.11. Classification of landcover dataset

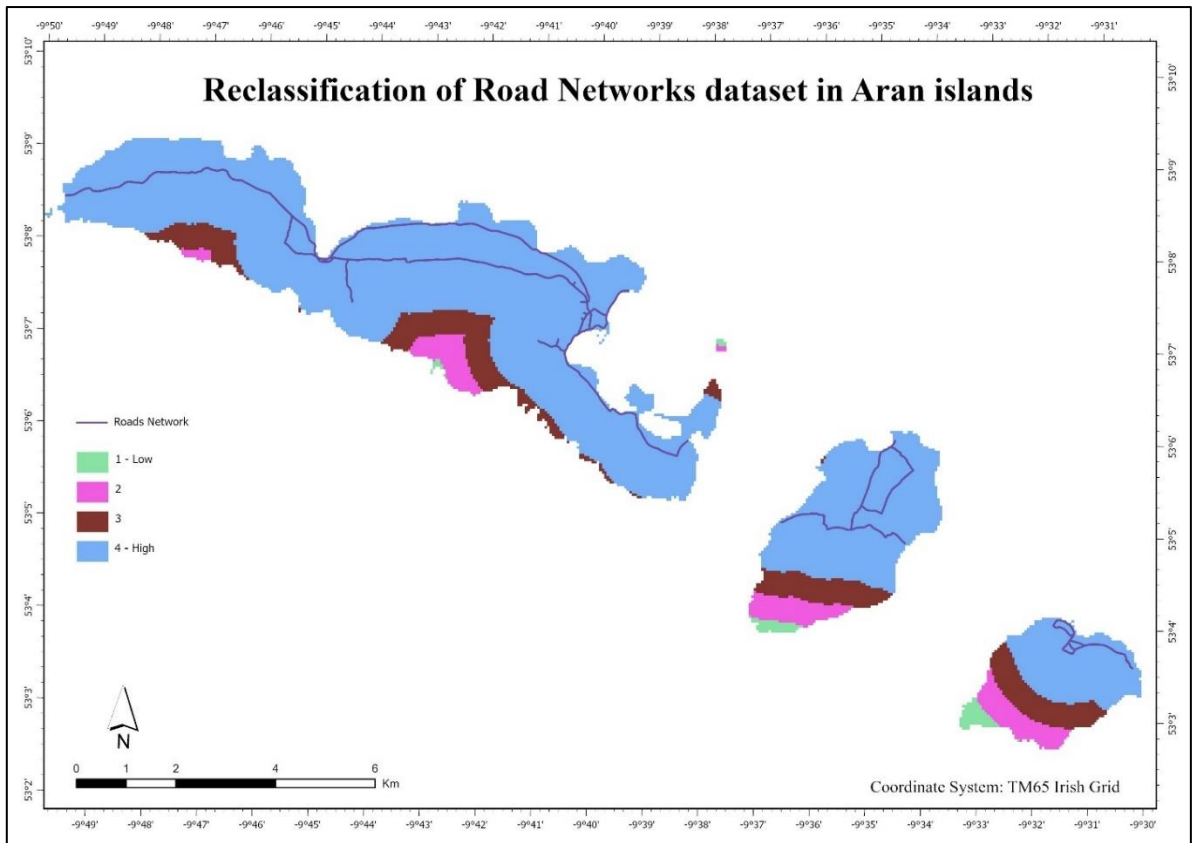


Figure 6.12. Reclassification of road networks dataset

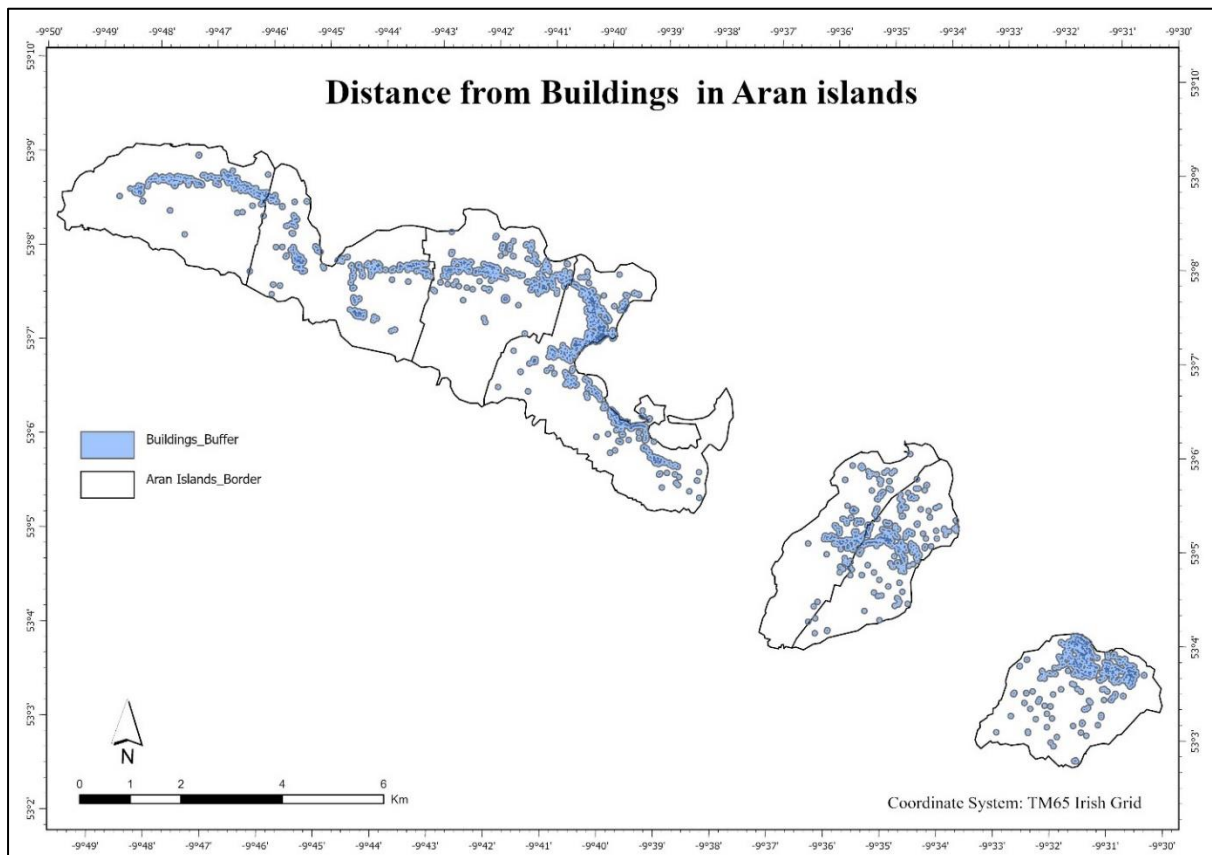


Figure 6.13. Distance from buildings

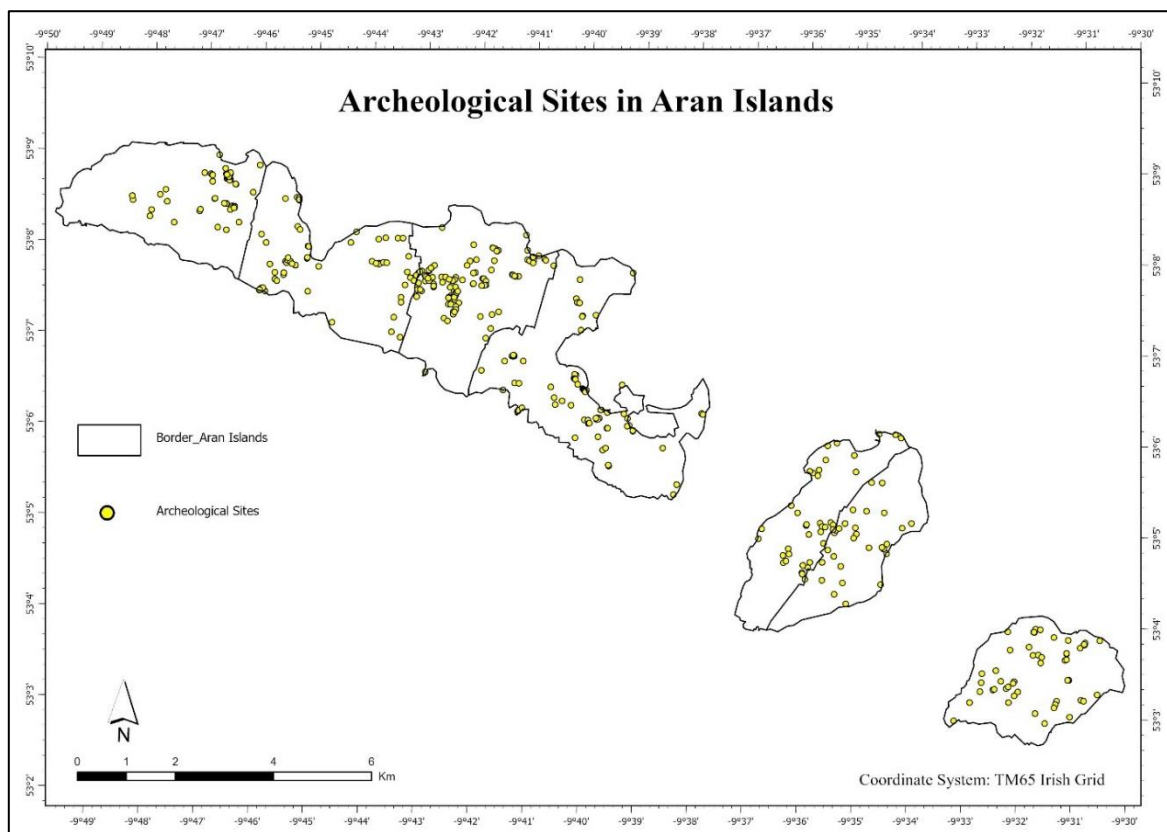


Figure 6.14. Archaeological sites in Aran Islands

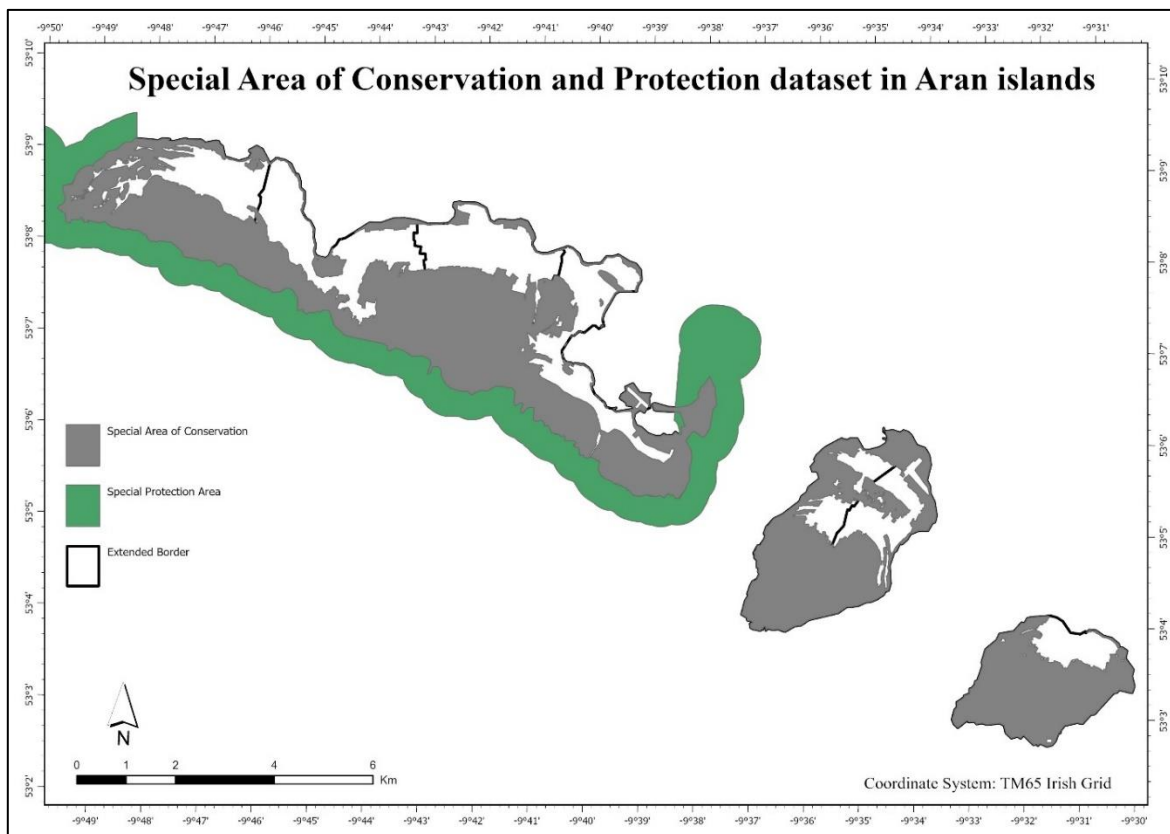


Figure 6.15. Special Area of Conservation and Special Protection Area dataset

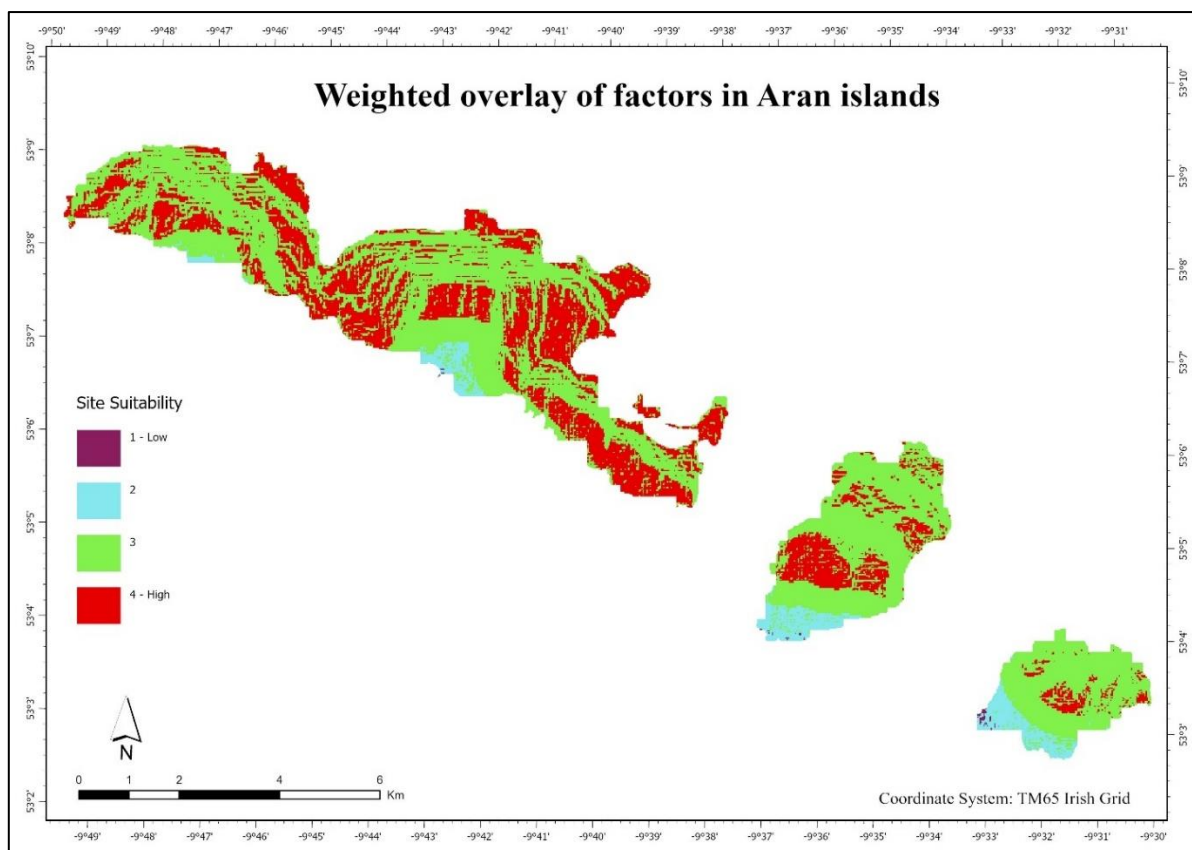


Figure 6.16. Weighted overlay of factors layer

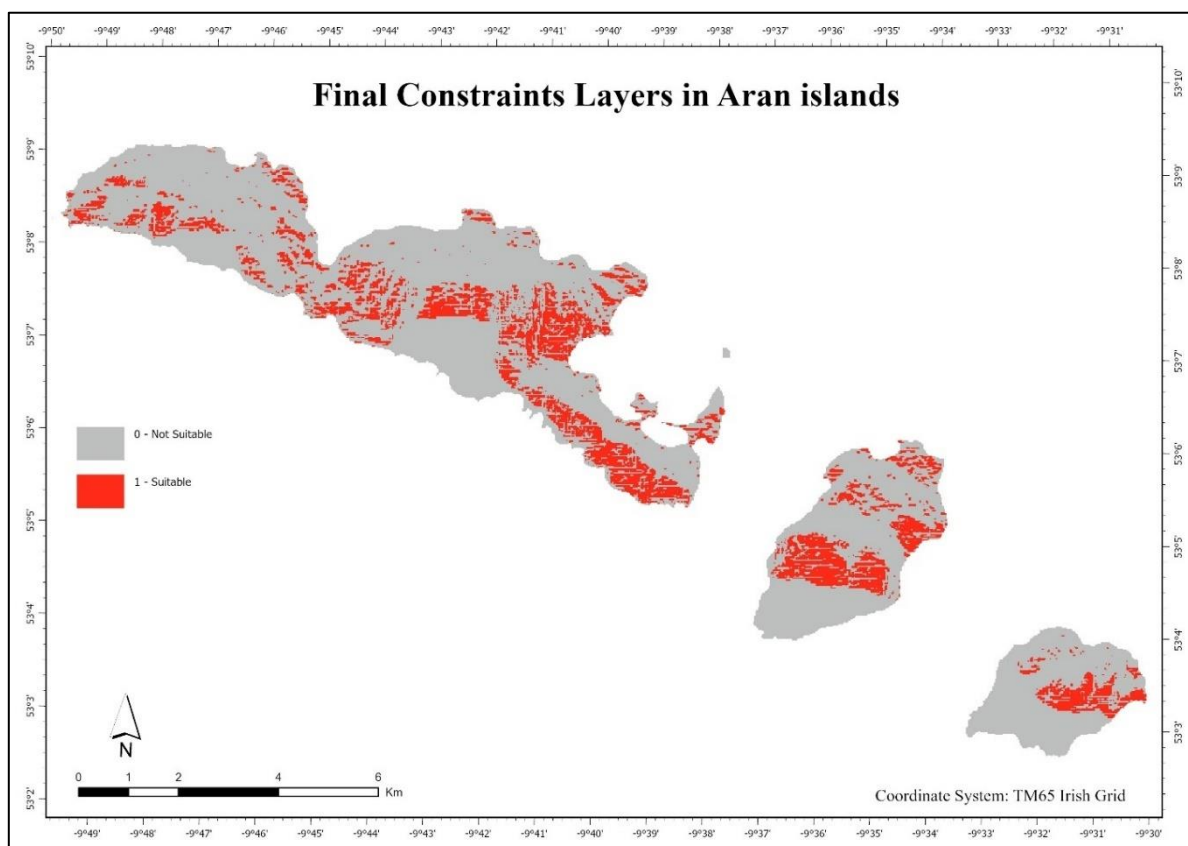


Figure 6.17. Final constraint layer

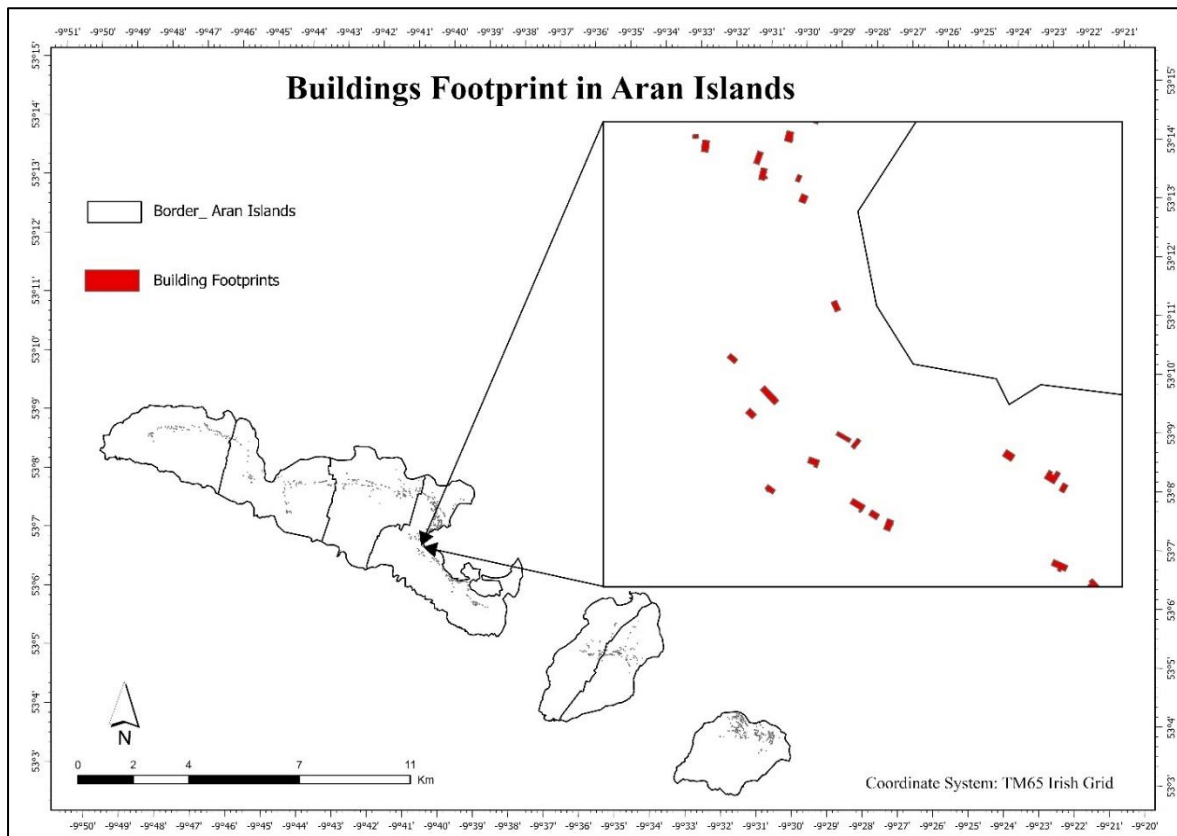


Figure 6.18. Building footprints in the Aran Islands

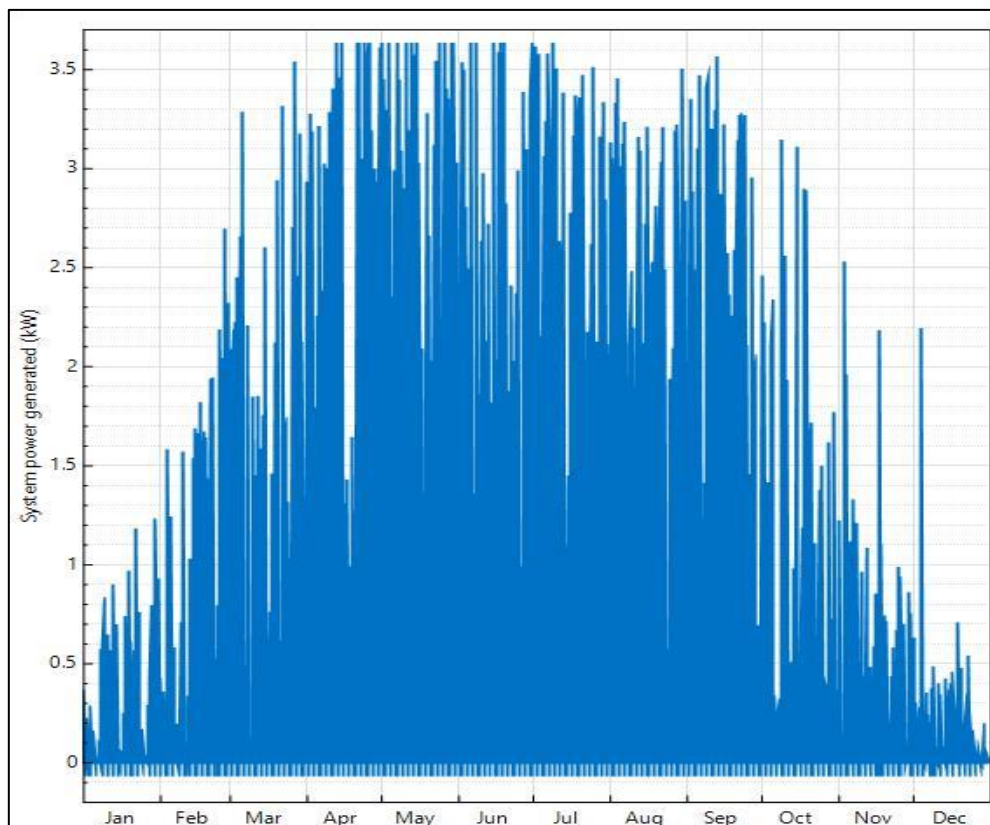


Figure 6.19. Solar power generation southwest-facing system

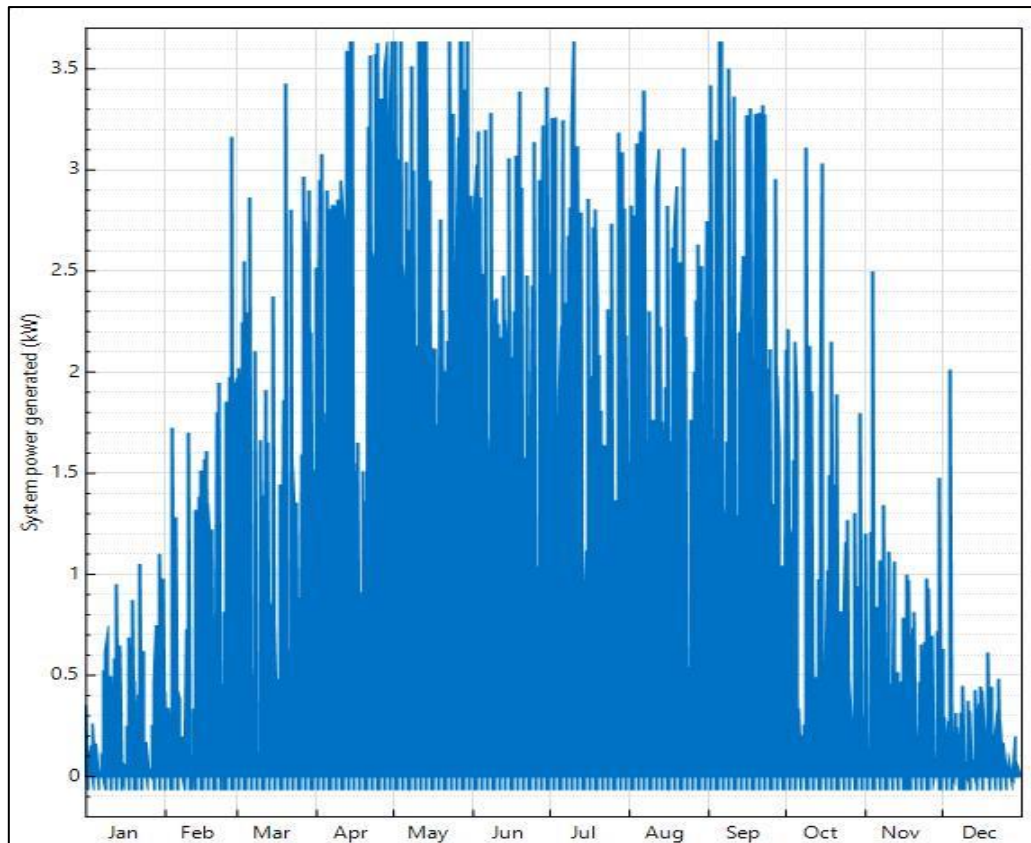


Figure 6.20. Solar power generation southeast-facing system

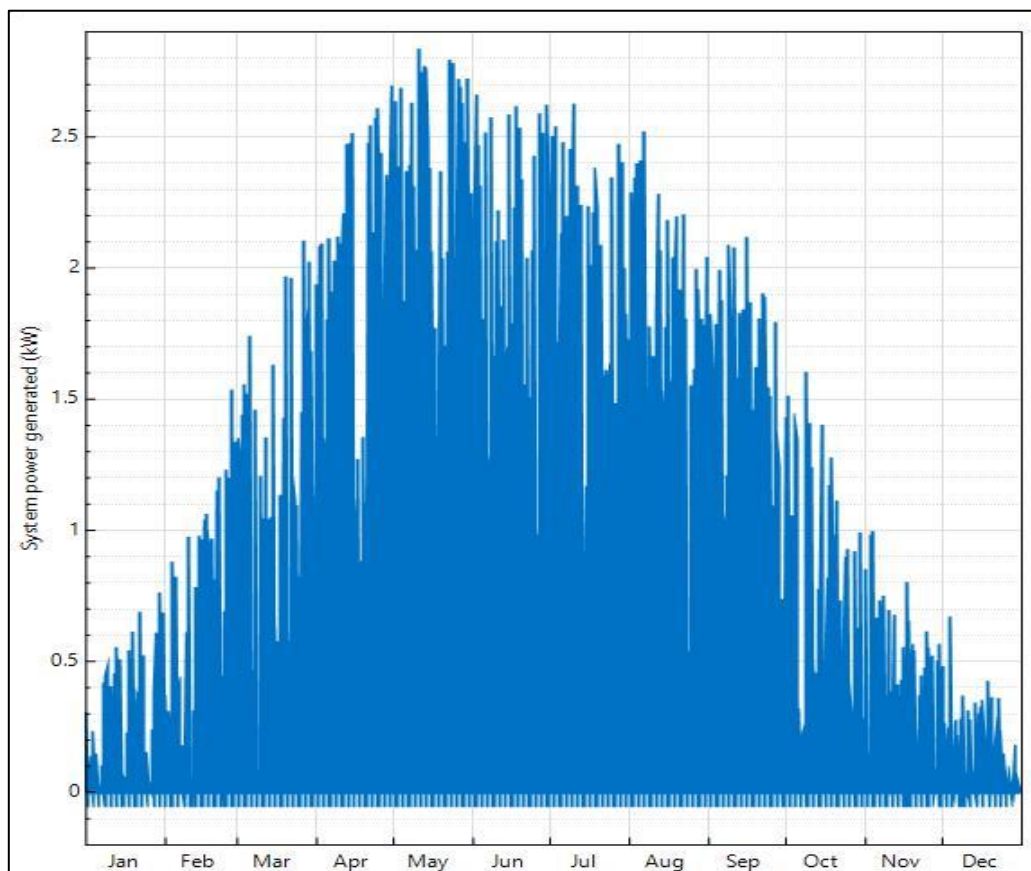


Figure 6.21. Solar power generation east and west facing system

6.2.3 Wind

Table 6.2. Data sources

Description	Tools	Source	Data Type	Resolution
Proximity to buildings	Euclidean Distance & Reclassify	(Open Street Map, 2024a)	Shapefile	-
Land cover	Lookup	(ESA, 2020b)	Raster	10-m
Power Density	Reclassify	(Global Wind Atlas, 2024)	Raster	100-m
Slope	Reclassify	(USGS, 2024)	Raster	30-m
Proximity to roads network	Euclidean Distance & Reclassify	(Open Street Map, 2024a)	Shapefile	-

Table 6.3. IEC wind classes

Source: (LM Wind Power, n.d.)

IEC Wind Classes				
	I (High Wind)	II (Medium Wind)	III (Low Wind)	IV (Very Low Wind)
Reference Wind Speed	50 m/s	42.5 m/s	37.5 m/s	30 m/s
Annual Average Wind Speed (Max)	10 m/s	8.5 m/s	7.5 m/s	6 m/s

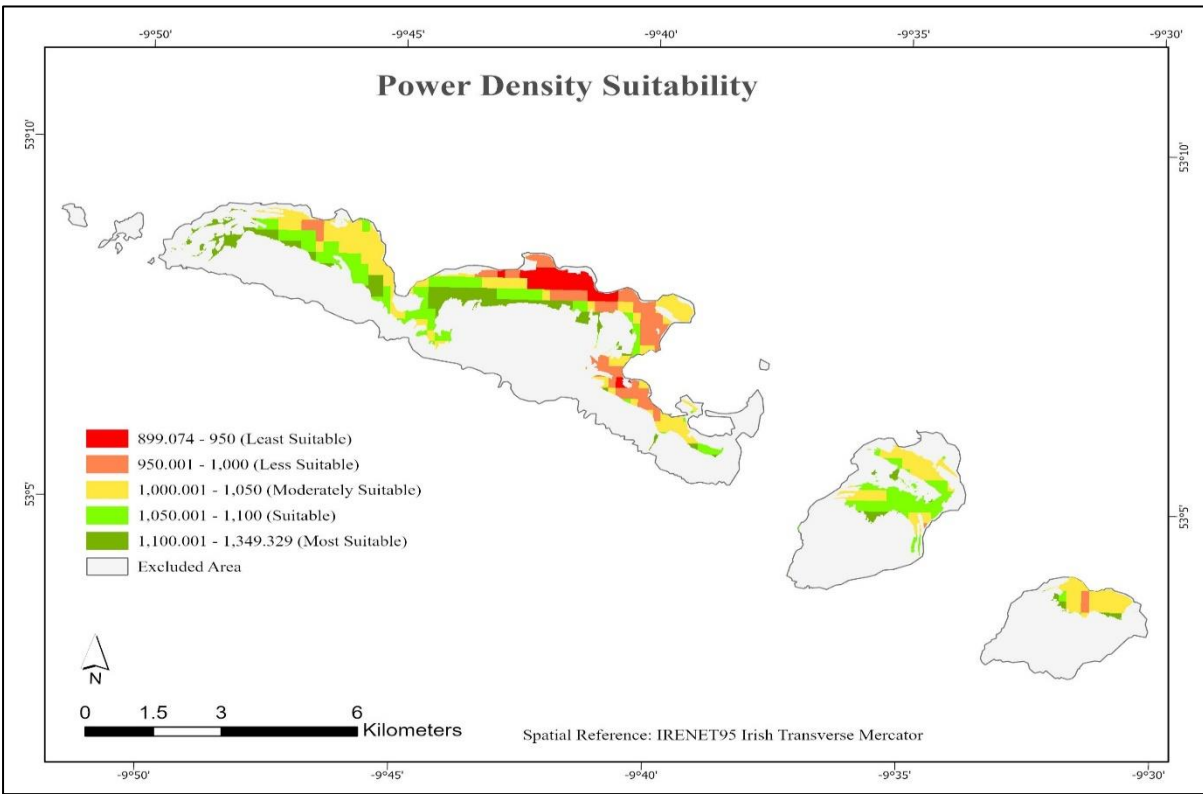


Figure 6.22. Power density suitability map

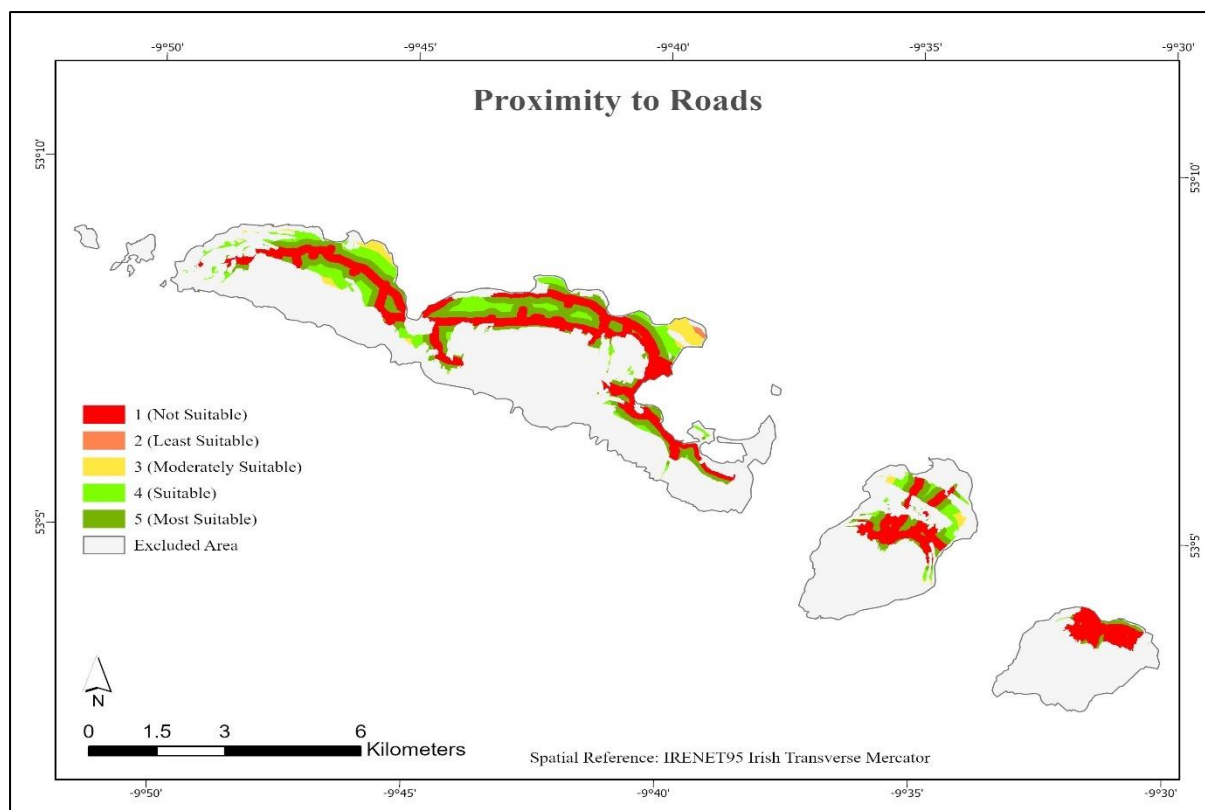


Figure 6.23. Proximity to roads suitability map

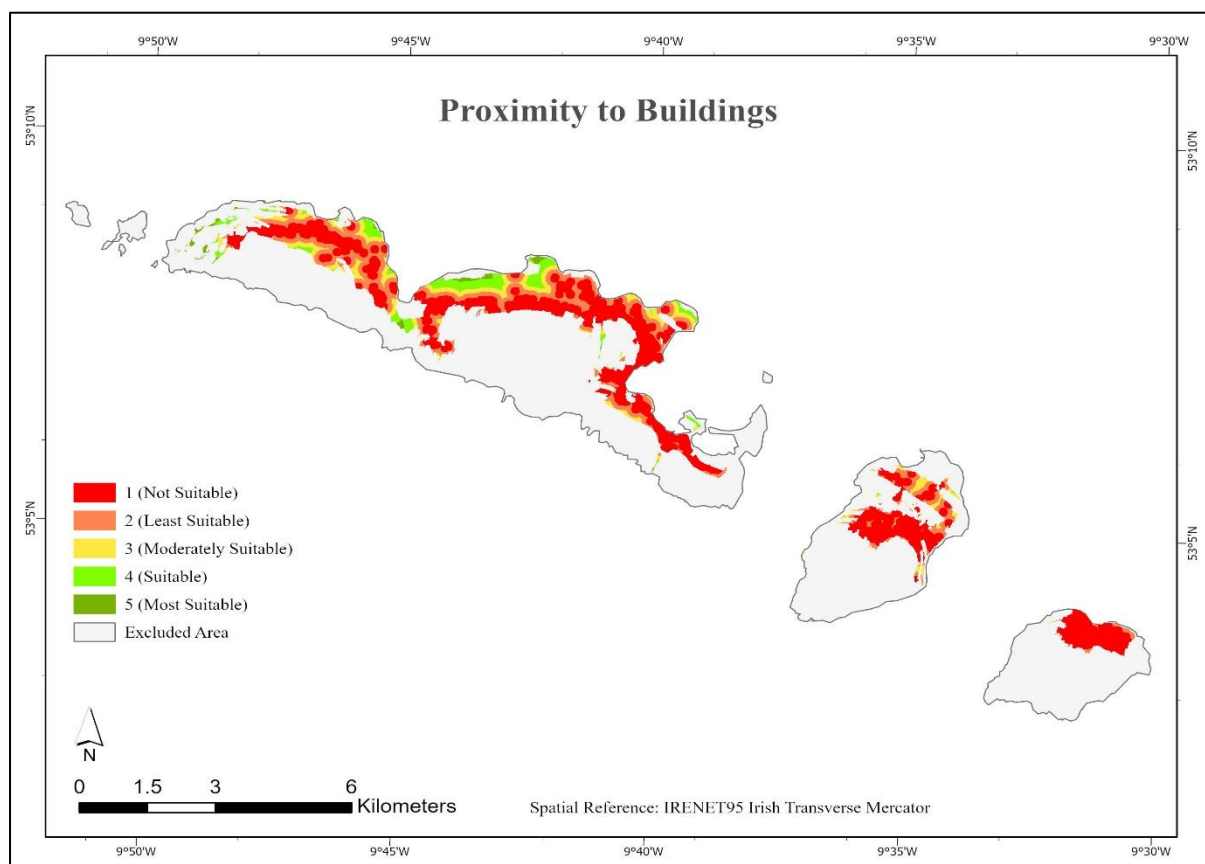


Figure 6.24. Proximity to buildings suitability map

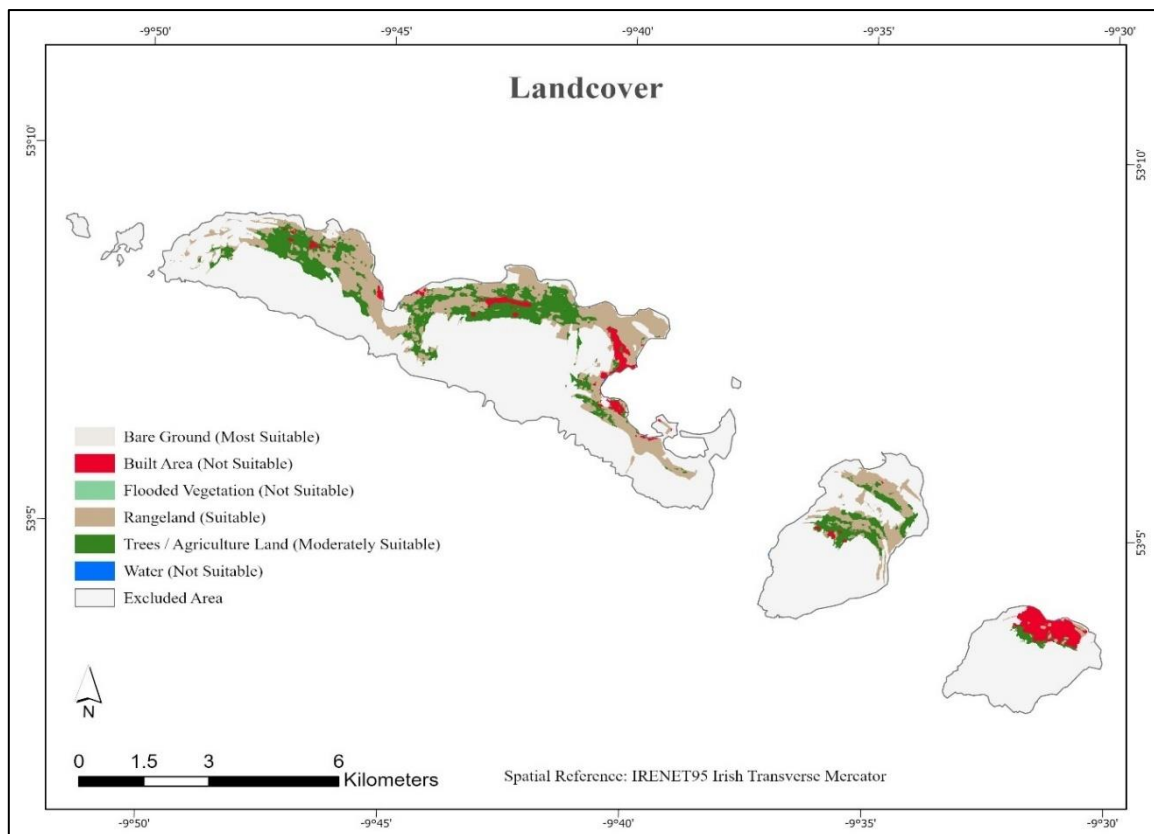


Figure 6.25. Landcover suitability map

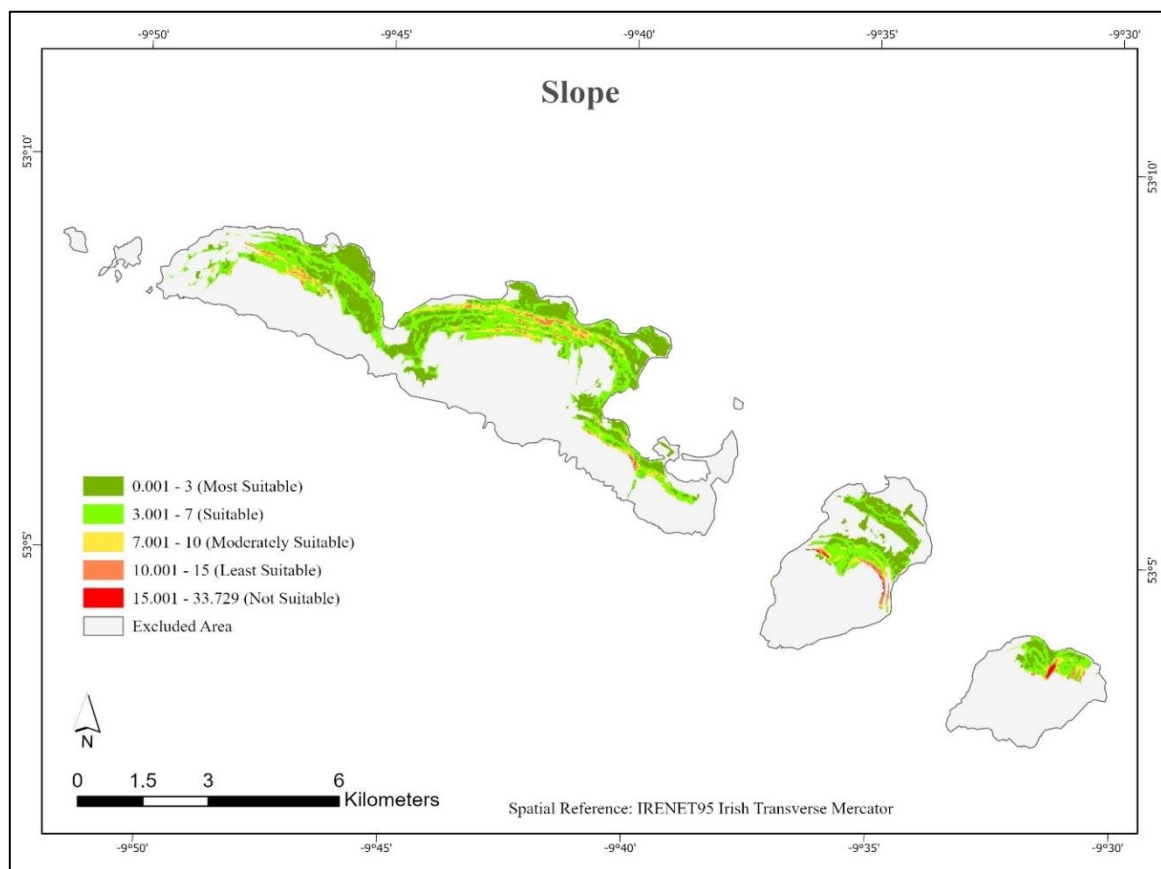


Figure 6.26. Slope suitability map

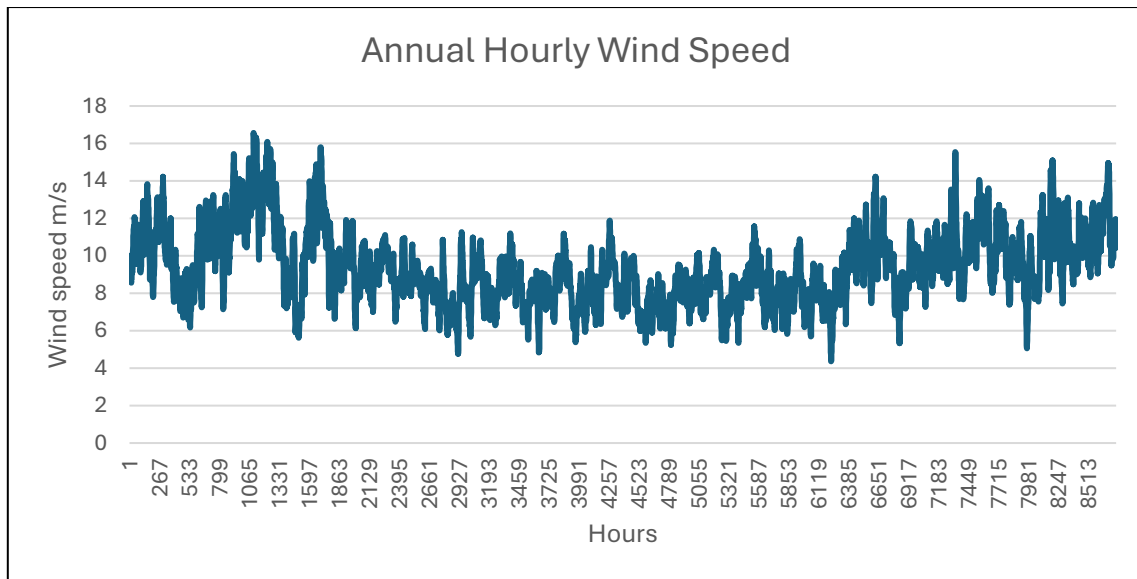


Figure 6.27. Annual hourly wind speed graph at 80m.

Source: (Renewables Ninja, n.d.)

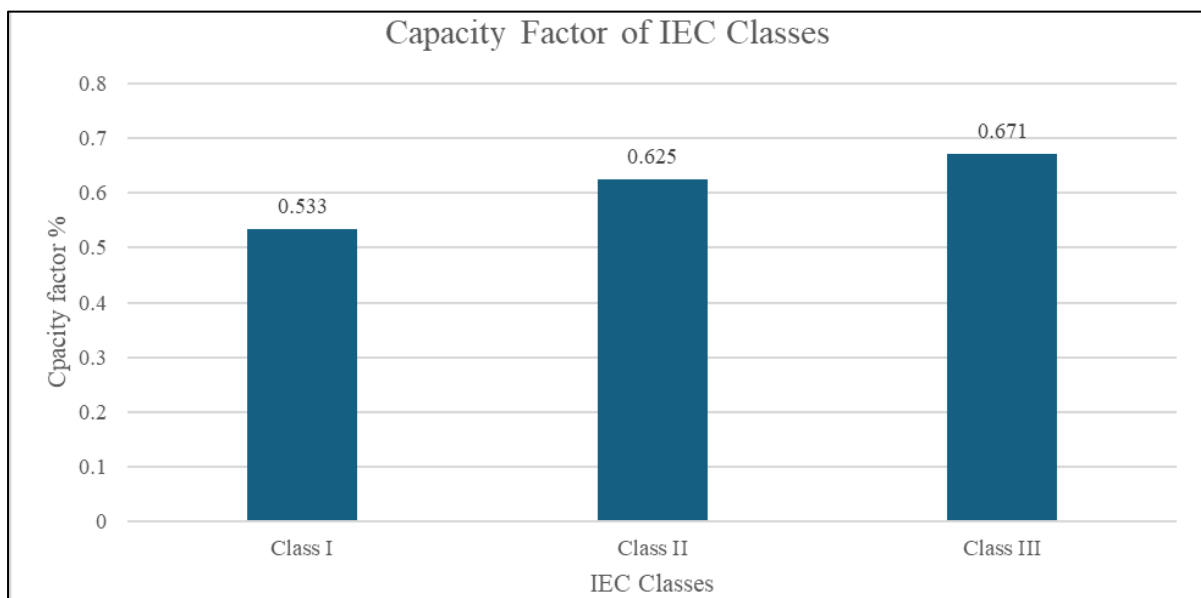


Figure 6.28. Capacity factor of IEC classes

Source: (Alamgeer, 2021)

Table 6.4. Technical data of Enercon E82 EP2 E4

Source: (Enercon, n.d.-a)

Technical Data	
Rated Power	2350 Kw
Rotor Diameter	82 m
Hub Height	78 m
Wind Class	IEC IA
Turbine Concept	Gearless, variable speed, Direct drive
Swept Area	5281 m2

Project:
Wind Farm at location 1

Licensed user:
Hochschule Flensburg, University of Applied Sciences
Darf nur für Zwecke der Lehre verwendet werden
--

student / weti-lab-vt16@hs-flensburg.de
Calculated:
2/21/2025 2:58 PM/4.0.547

PARK - Main Result

Calculation: Park 1

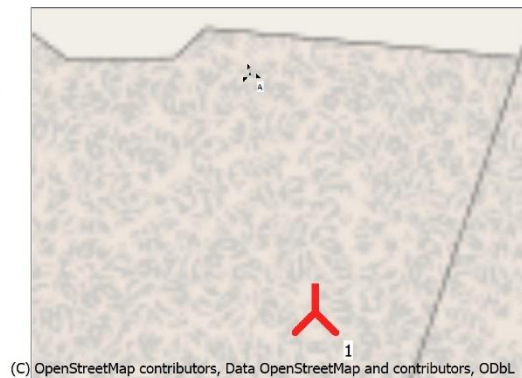
Wake Model N.O. Jensen (RISØ/EMD) Park 2 2018

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: -0.5°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: GALWAY V3 2014
Base temperature: 9.9 °C at 18.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 18.4 m + 78.0 m = 1.235 kg/m³ -> 100.8 % of Std
Relative humidity: 0.0 %

Wake Model Parameters
Wake decay constant 0.090 DTU default onshore
Hub height independent

Wake calculation settings
Angle [°] Wind speed [m/s]
start end step start end step
0.5 360.0 1.0 0.5 34.0 1.0



(C) OpenStreetMap contributors, Data OpenStreetMap and contributors, ODbL

Scale 1:500
New WTG Meteorological Data

Key results for height 78.0 m above ground level

Terrain Geo [deg]-WGS84

Longitude	Latitude	Name of wind distribution	Height [m]	Type	Wind energy [kWh/m²]	Mean wind speed [m/s]
A -9.590893° E	53.091940° N	ERA5(T) Rectangular Grid_N53.00_W009.50 (3)	100.0	WEIBULL	6,372	8.7

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK	Result-10.0% [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	9,513.3	8,561.9	9,513.3	0.0	41.6	8,561.9	3,643	8.7

*) Based on Result-10.0%

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

WTG type				Power curve				Annual Energy			
Links	Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Creator Name	Result	Result-10.0%	Wake loss	Free mean wind speed
1 A	Yes	ENERCON	E-82 E4-2,350	[kW] 2,350	[m] 82.0	[m] 78.3	EMD Mode 00 - OM 0 (2350 kW)	[MWh/y] 9,513.3	[MWh/y] 8,562	[%] 0.0	[m/s] 8.73

WTG siting

Geo [deg]-WGS84

Longitude	Latitude	Z [m]	Row data/Description
1 New -9.590807° E	53.091753° N	19.0	ENERCON E-82 E4 2350 82.0 !O! hub: 78.3 m (TOT: 119.3 m) (1)

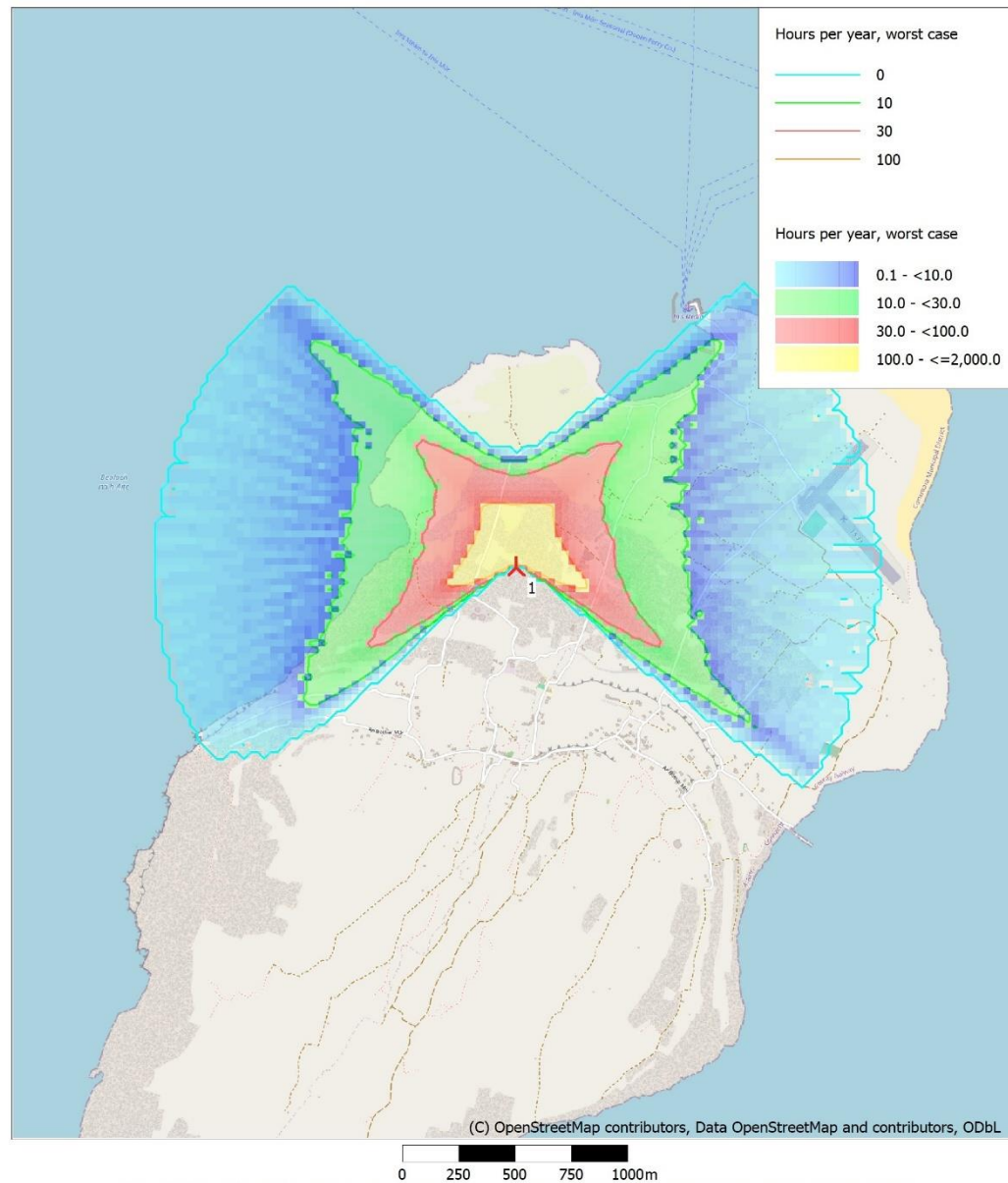
Figure 6.29. Energy yield result for suitable location at Inishmaan

Project:
Wind Farm at location 1

Licensed user:
Hochschule Flensburg, University of Applied Sciences
Darf nur für Zwecke der Lehre verwendet werden
--

student / weti-lab-vt16@hs-flensburg.de
Calculated:
2/21/2025 9:19 PM/4.0.547

SHADOW - Map



New WTG

Map: EMD OpenStreetMap, Print scale 1:25,000, Map center Geo WGS84 East: -9.590724° E North: 53.091747° N

Flicker map level: Project Wizard Elevation Data Grid (SRTM: Shuttle DTM 3 arc-second)
Time step: 4 minutes, Day step: 14 days, Map resolution: 30 m, Visibility resolution: 15 m, Eye height: 1.5 m

windPRO 4.0.547 by EMD International A/S, Tel. +45 69 16 48 50, www.emd-international.com, support@emd.dk

2/22/2025 3:09 PM / 1

windPRO

Figure 6.30. Shadow flicker effect results at Inishmaan

Project:
Wind Farm at location 1

Licensed user:
Hochschule Flensburg, University of Applied Sciences
Darf nur für Zwecke der Lehre verwendet werden
--

student / weti-lab-vt16@hs-flensburg.de
Calculated:
2/22/2025 3:12 PM/4.0.547

ZVI - Map Standard ZVI summary

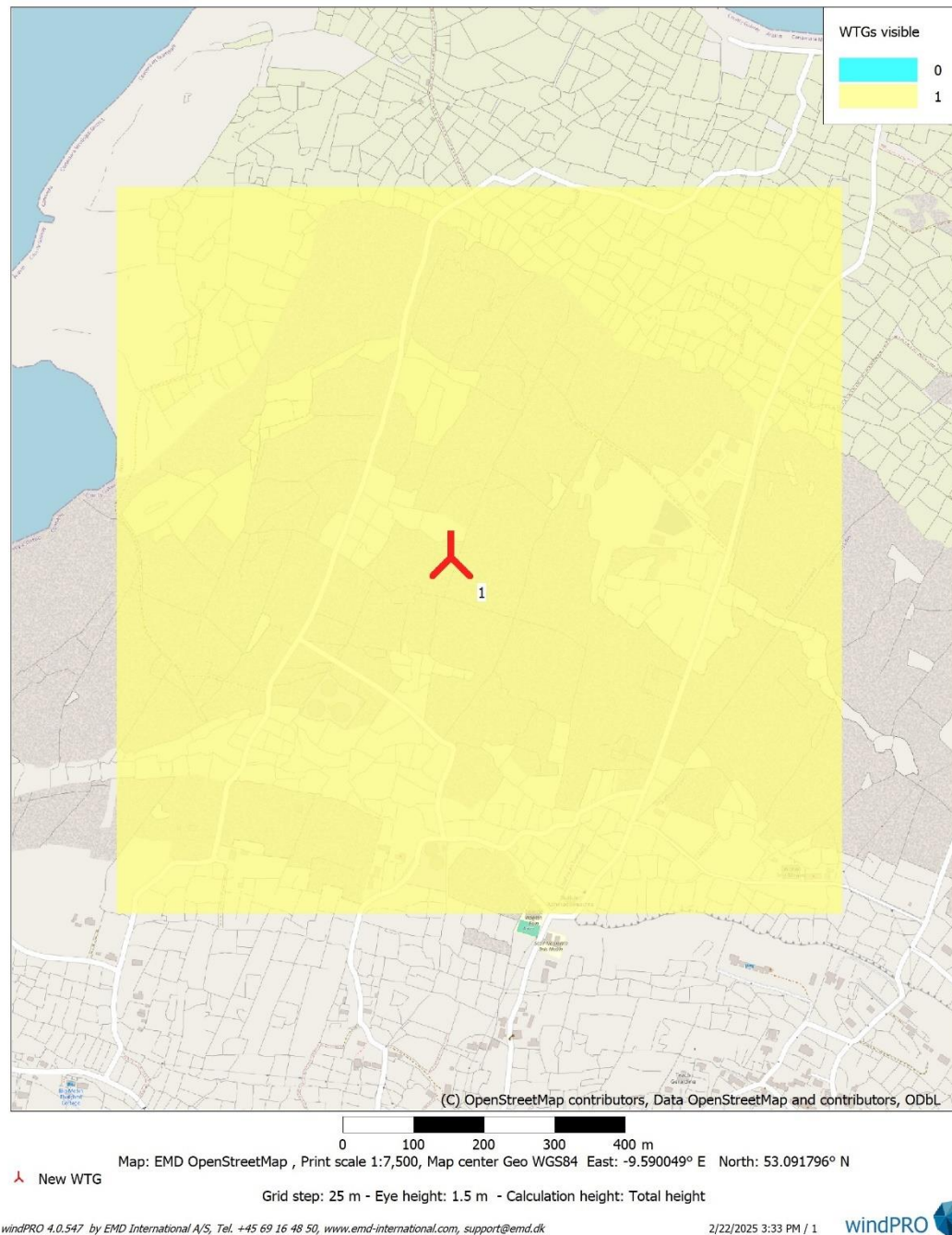


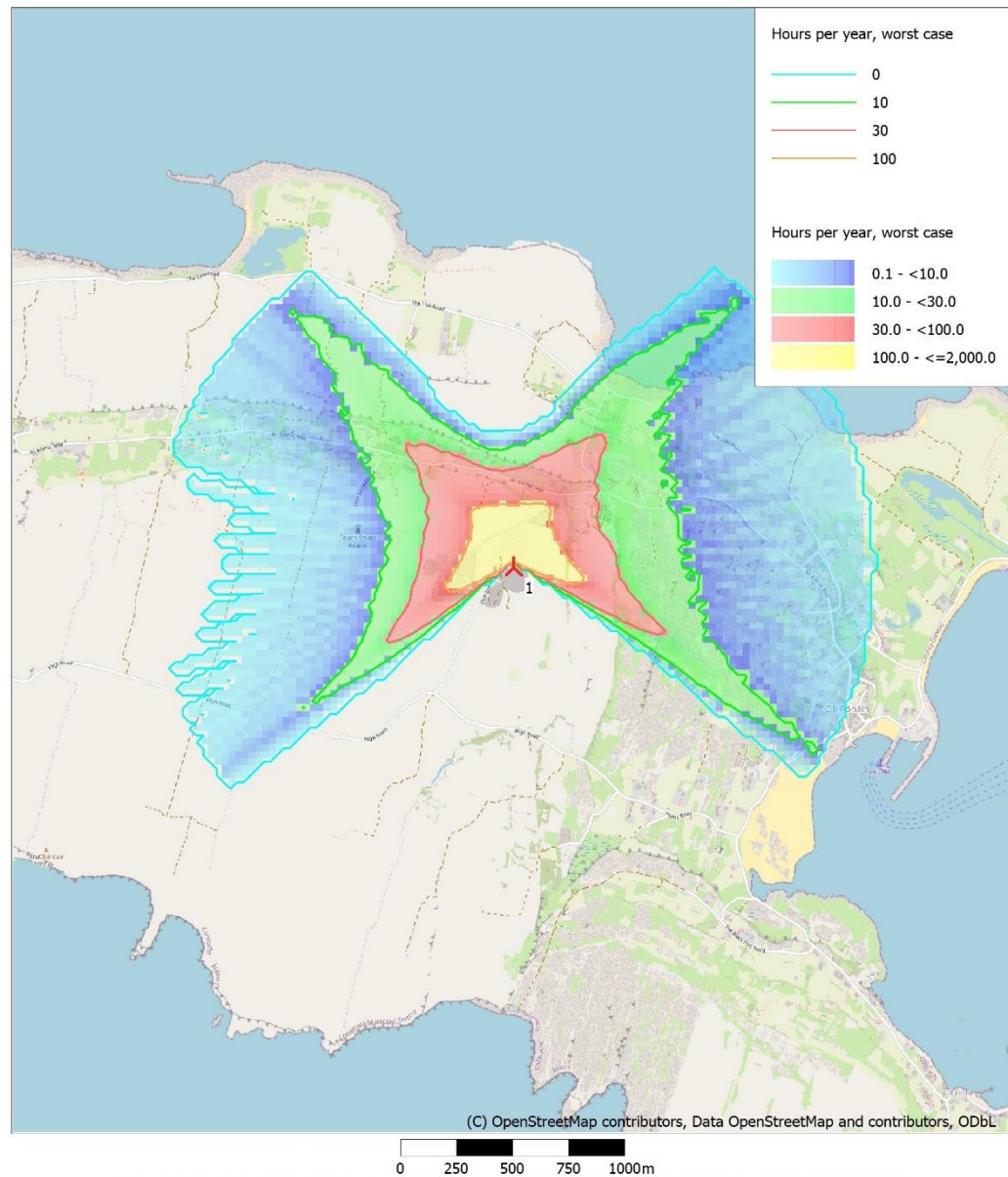
Figure 6.32. Visibility evaluation result at Inishmaan

Project:
Wind Turbine at location 3

Licensed user:
Hochschule Flensburg, University of Applied Sciences
Darf nur für Zwecke der Lehre verwendet werden
--

student / weti-lab-vt16@hs-flensburg.de
Calculated:
2/22/2025 3:26 PM/4.0.547

SHADOW - Map



New WTG

Map: EMD OpenStreetMap , Print scale 1:25,000, Map center Geo WGS84 East: -9.691622° E North: 53.125992° N

Flicker map level: Project Wizard Elevation Data Grid (SRTM: Shuttle DTM 3 arc-second)
Time step: 4 minutes, Day step: 14 days, Map resolution: 30 m, Visibility resolution: 15 m, Eye height: 1.5 m

windPRO 4.0.547 by EMD International A/S, Tel. +45 69 16 48 50, www.emd-international.com, support@emd.dk

2/22/2025 3:26 PM / 1

windPRO 

Figure 6.34. Shadow flicker effect results at Inishmore

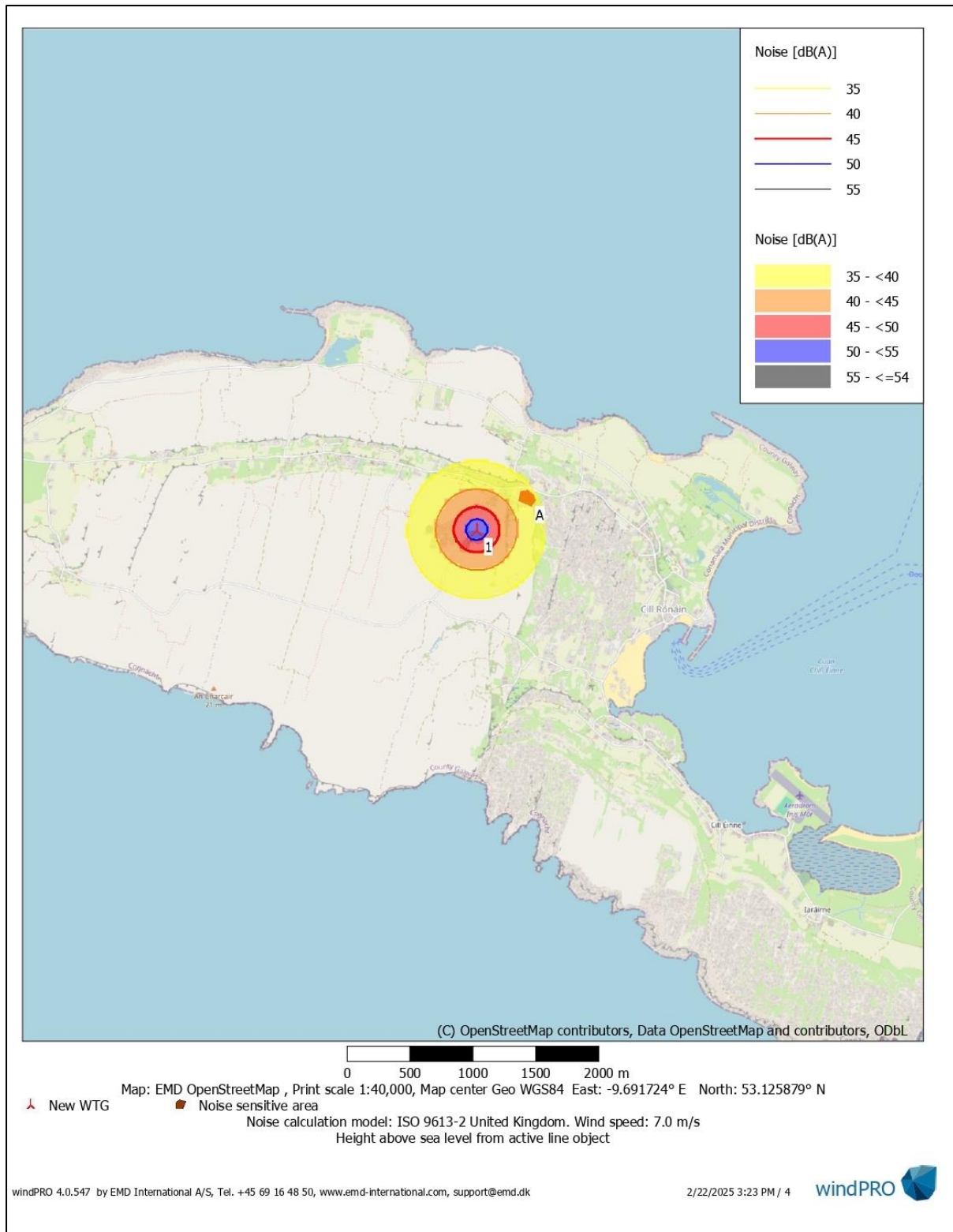


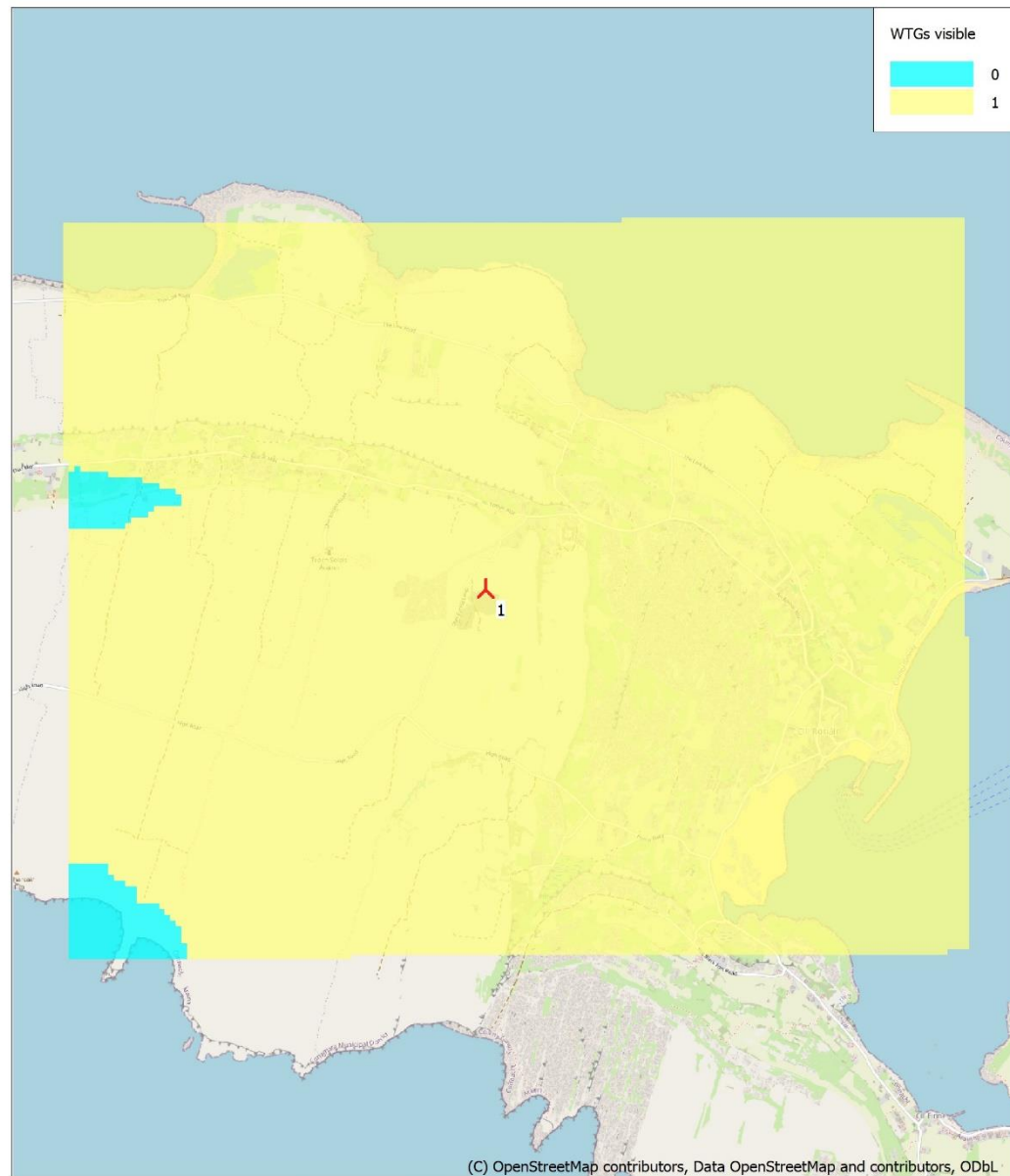
Figure 6.35. Noise effect result at Inishmore

Project:
Wind Turbine at location 3

Licensed user:
Hochschule Flensburg, University of Applied Sciences
Darf nur für Zwecke der Lehre verwendet werden
--

student / weti-lab-vt16@hs-flensburg.de
Calculated:
2/22/2025 3:21 PM/4.0.547

ZVI - Map Standard ZVI summary



0 250 500 750 1000m

Map: EMD OpenStreetMap, Print scale 1:25,000, Map center Geo WGS84 East: -9.689598° E North: 53.125968° N

New WTG

Grid step: 25 m - Eye height: 1.5 m - Calculation height: Total height

windPRO 4.0.547 by EMD International A/S, Tel. +45 69 16 48 50, www.emd-international.com, support@emd.dk

2/22/2025 3:21 PM / 1

windPRO

Figure 6.36. Visibility evaluation result at Inishmore

Table 6.5. Comparison of WindPro results for suitable locations

Location	Annual Energy Generation [MWh/y]	Capacity Factor [%]	Annual Full load hours [hours/year]	Mean Wind Speed @ 80m height	Noise Impact (db)	Shadow Flicker (hours)	Visibility
Cnriotáil (Inishmaan)	8561	41.6	3643	8.7	44	30	Yes
Dun Eochla (Inishmore)	8613	41.8	3665	8.8	45	60	Yes
Aran Walkers Lodge (Inishmore)	8631	41.9	3673	8.8	55	70	Yes

6.2.4 Wave

All maps are based on Selkie Project Web-Based GIS (HORGAN, 2020).

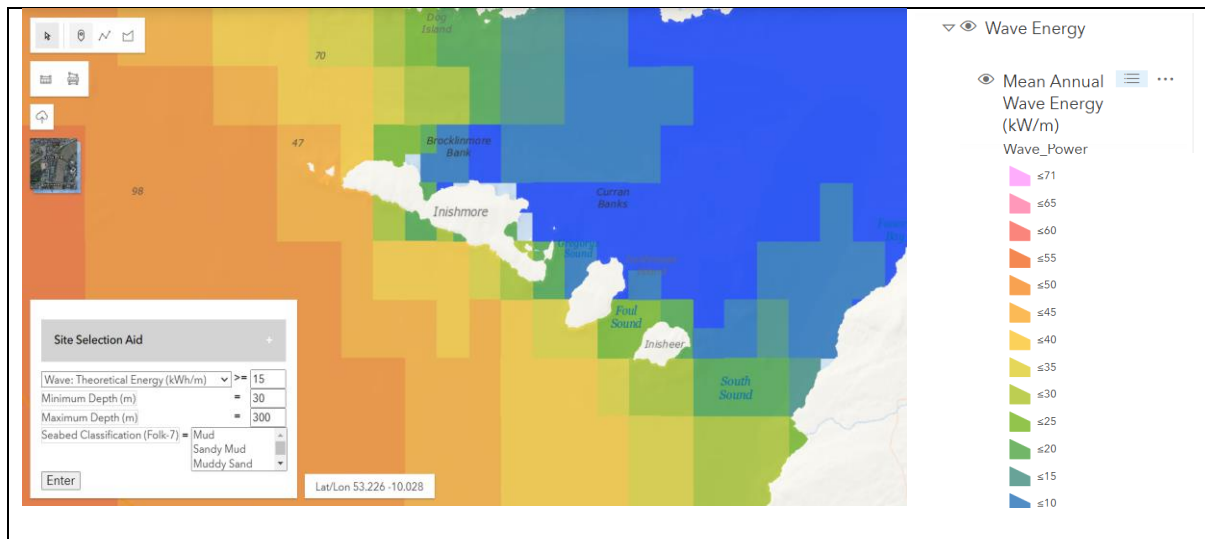


Figure 6.37. The annual mean wave power resource (kW/m metre of wave crest)

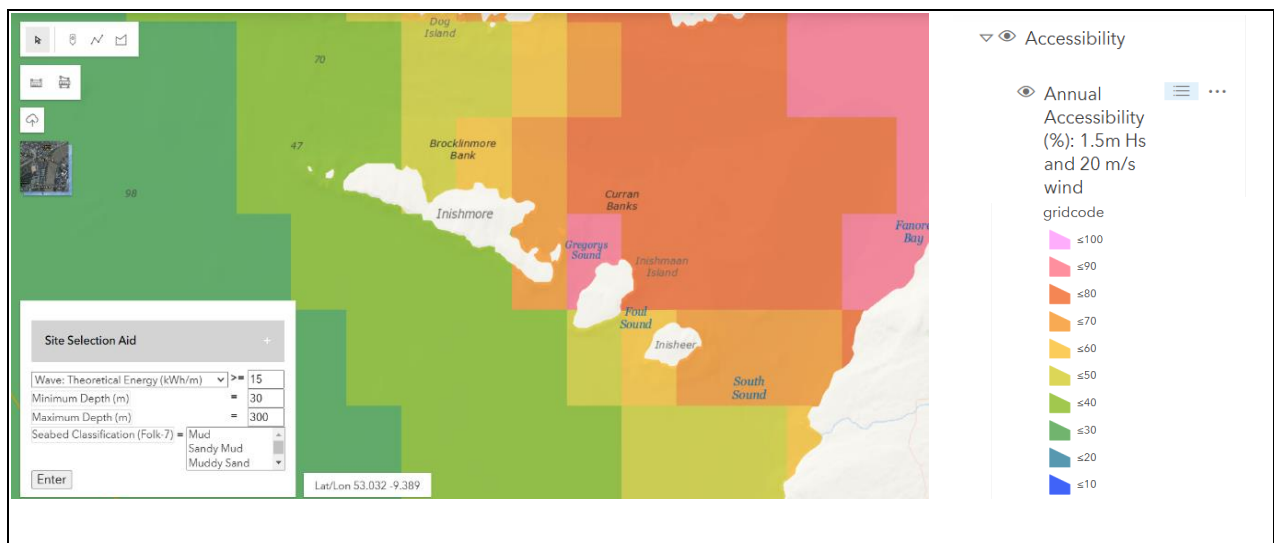


Figure 6.38. Annual accessibility based on CTV operating limits

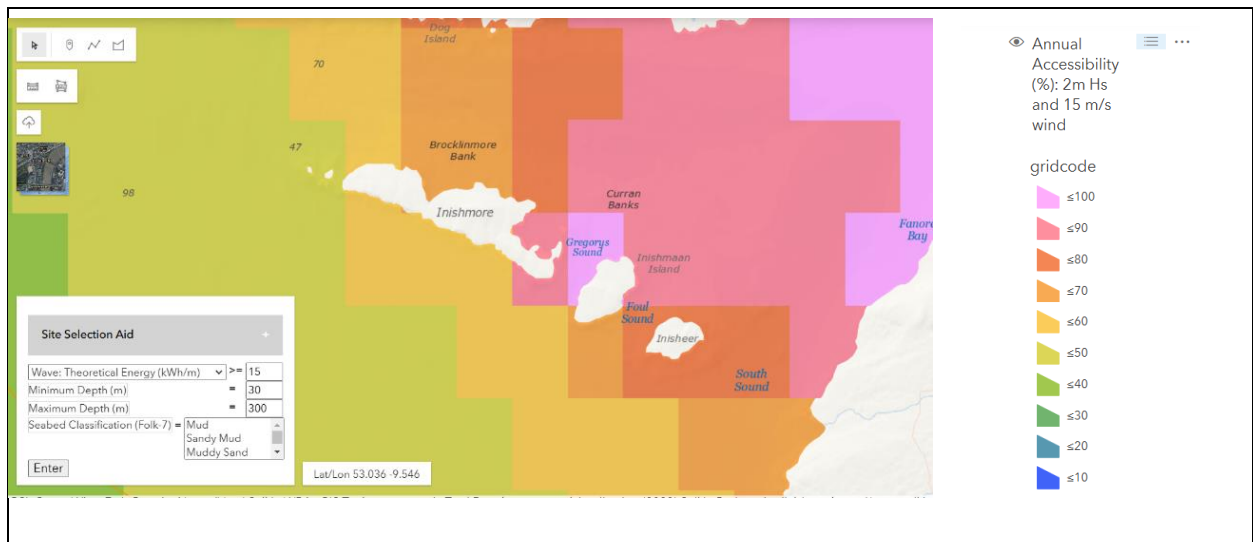


Figure 6.39. Annual accessibility based on HLV operating limits

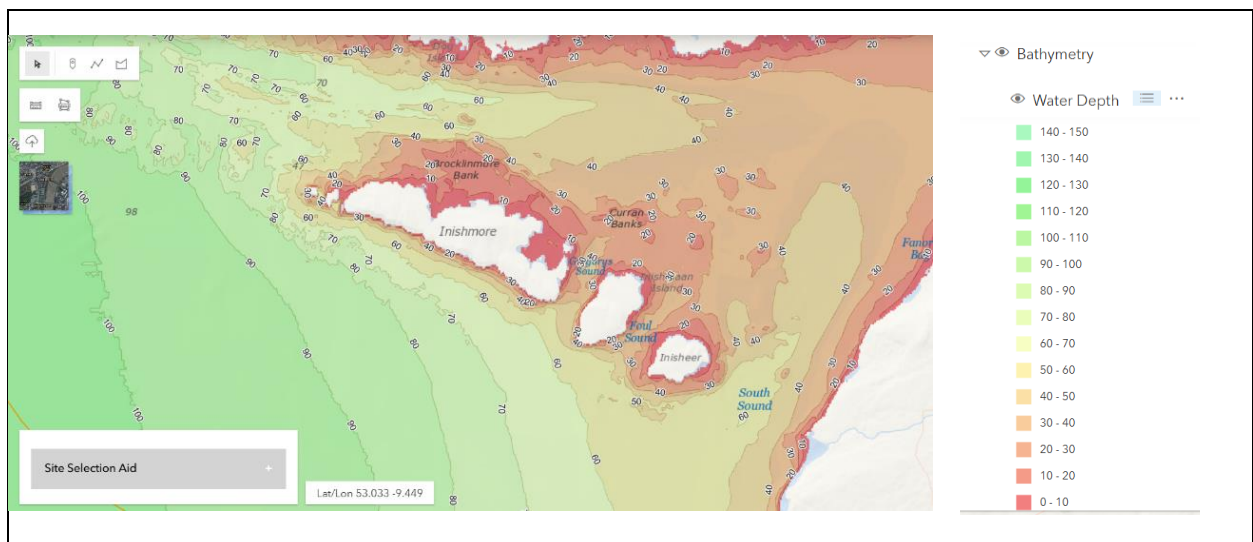


Figure 6.40. The water depth between 0 and 150

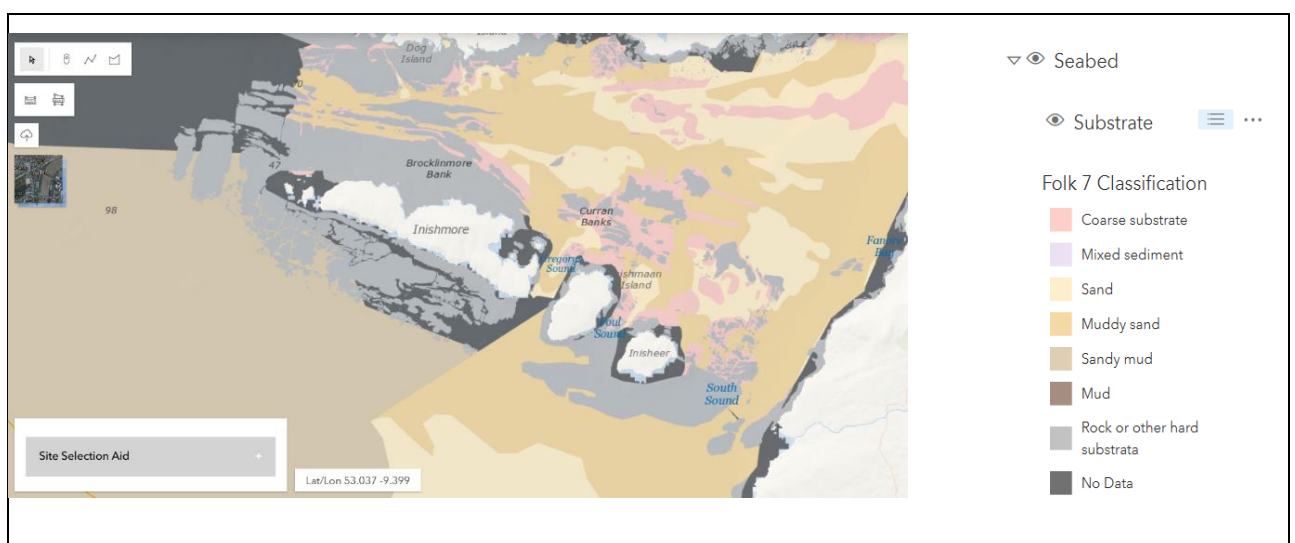


Figure 6.41. Folk 7 classification of Seabed character.

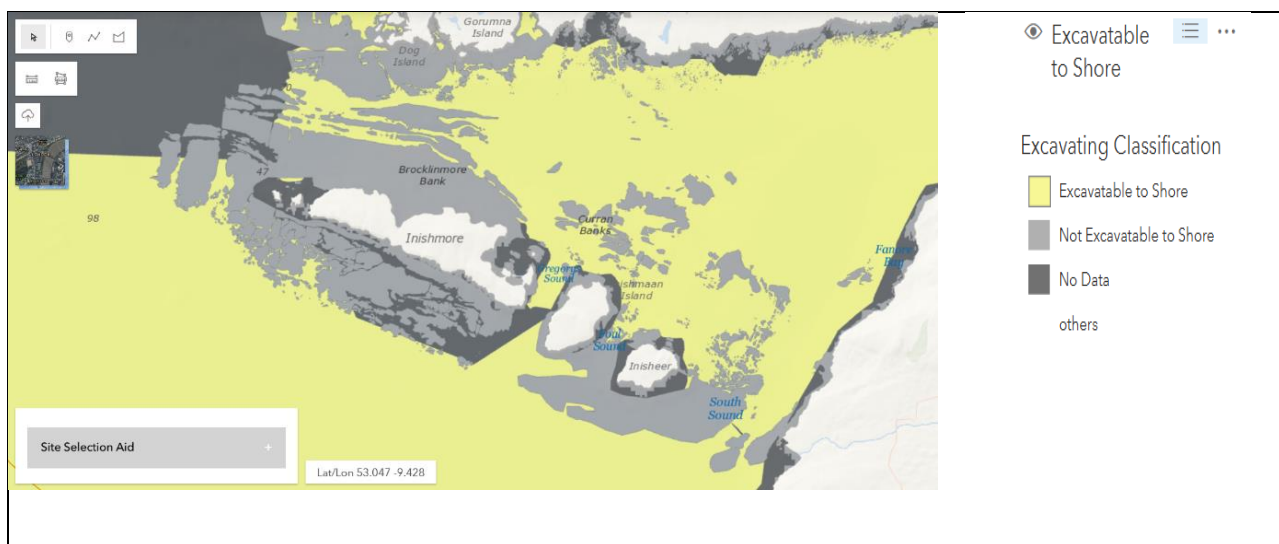


Figure 6.42. Excavatable areas

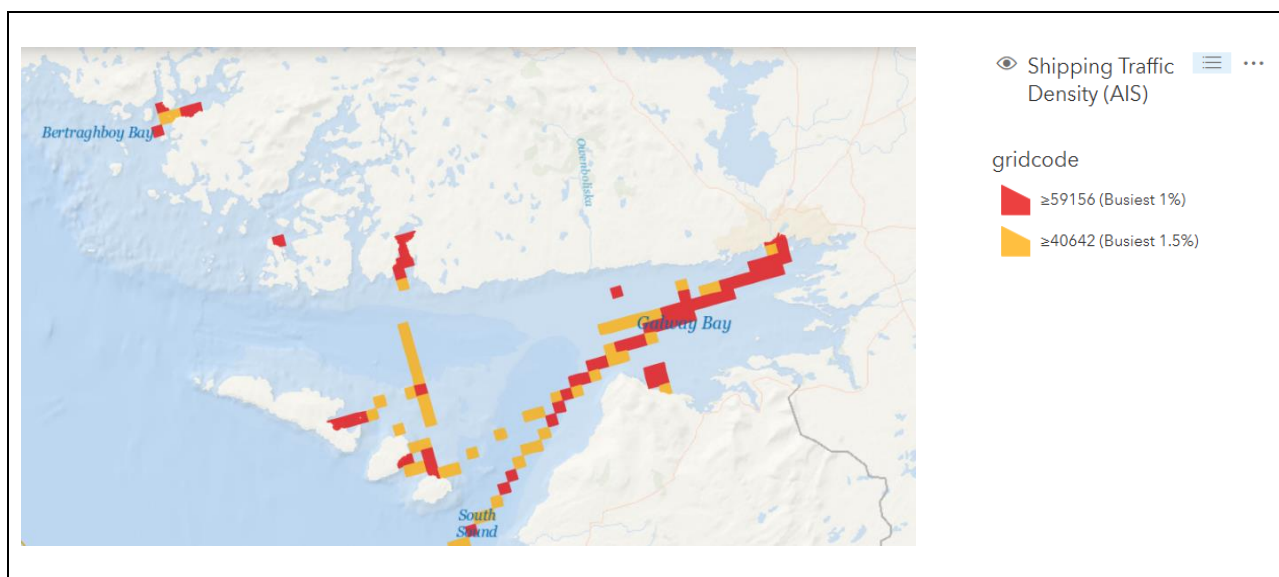


Figure 6.43. The busiest areas for general shipping

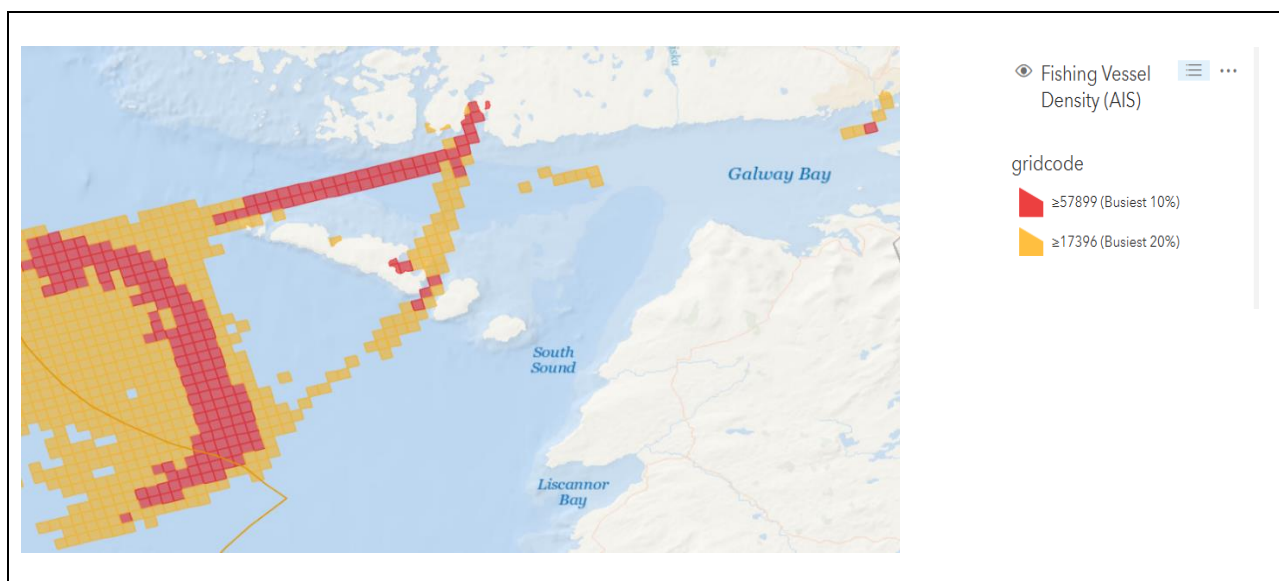


Figure 6.44. The busiest areas for fishing

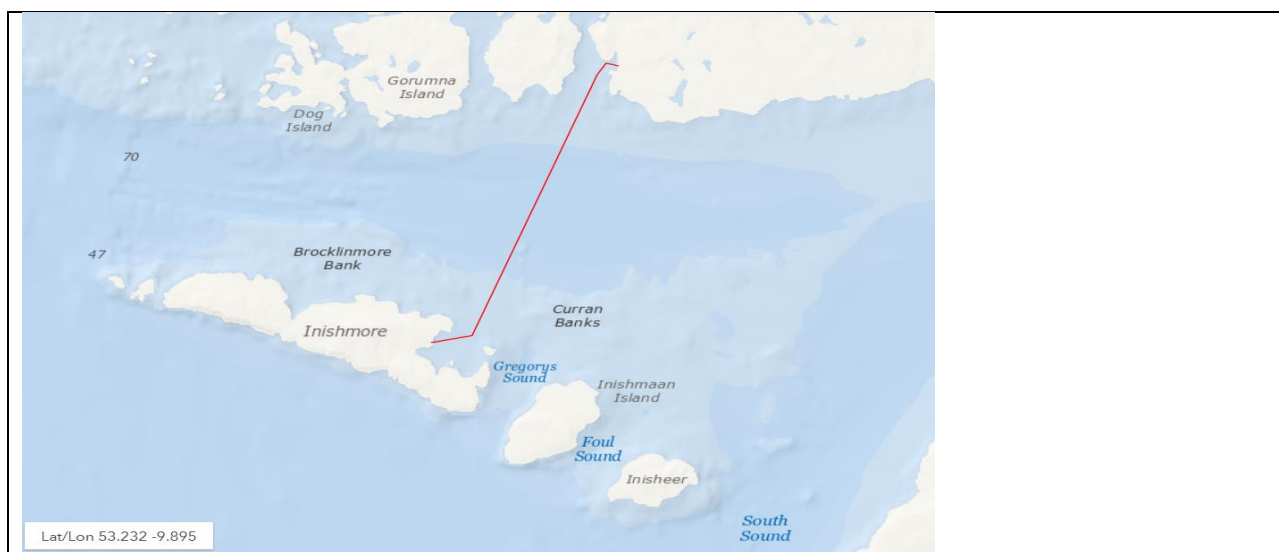


Figure 6.45. Subsea cable connecting Aran Island to the mainland

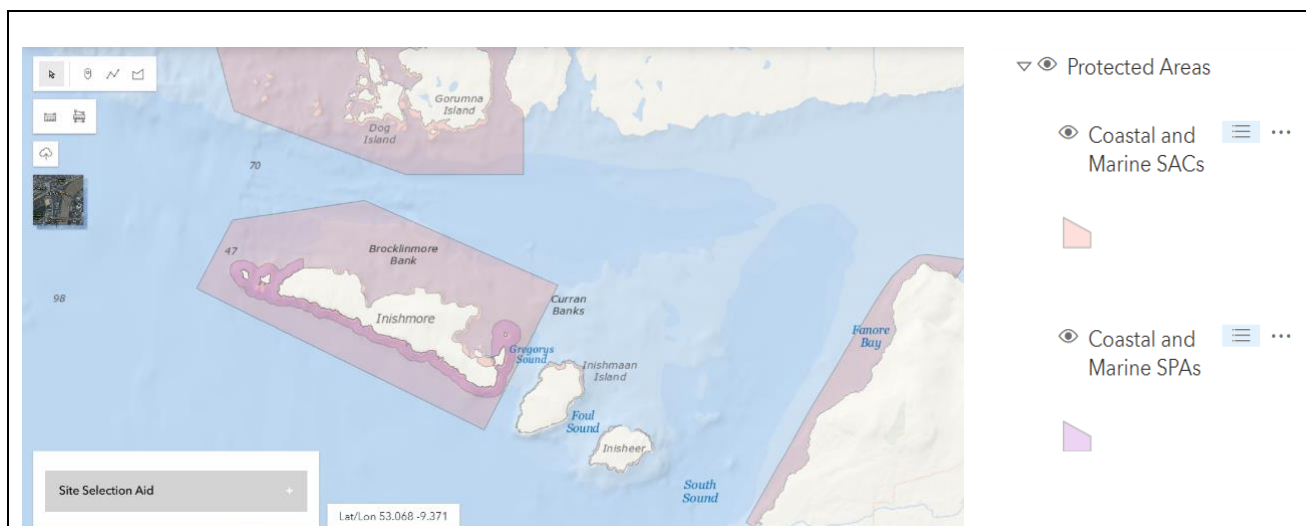


Figure 6.46. Protected areas

6.2.5 Other technologies resource assessment

6.2.5.1 Rooftop wind energy resource assessment

The viability of utilizing roof-mounted wind turbines on existing buildings in the Aran Islands, Ireland, is constrained by a combination of structural, regulatory and practical factors. Here is a brief breakdown for the same based on the covered market options, regulations, and the distinct energy consumption requirements of the buildings in the vicinity.

6.2.5.1.1 Structural and technical constraints

A major factor for considering the roof mounted wind turbines is the strength of the roofs. On the Aran Islands, for example, few traditional homes have thatched roofs and also most of the roofs are gable roof. A commercial small-scale model like the Ventum Dynamics turbine, whose rated power is 3kW and weighs more than 500 kilograms. This weight coupled with vibration would be a significant risk for the integrity of roofs.

6.2.5.1.2 Regulatory challenges

The regulatory framework for wind turbines in domestic and business settings, further restricts the feasibility of roof-mounted distributed turbines in the Aran Islands. Below are the key regulatory limitations:

Table 6.6. Key Regulatory limitations on rooftop wind turbines

Domestic Setting	Total turbine height should be less than 13 meters, rotor diameter should be less than 6 meters. Depending on the roof and turbine assembly, roof-mounted turbines may have even larger dimensions.
Placement Restrictions	The turbine may not be attached to a building or placed in front of one. Roof-mounted turbines are directly in violation of this requirement because they will be mounted on the roof.
Noise Levels	Noise should not exceed 43 dB(A) or 5 dB(A) above background levels at the nearest dwelling.

6.2.5.1.3 Industrial or business setting

Table 6.7. Key industrial or business setting limitations on rooftop wind turbines

Height and Clearance requirements	Individual turbine height can only reach 20 meters and the lowest plane, is at least 3 meters high from ground. The rules pertain to standalone turbines, not roof-mounted ones.
Safety Distances	There are also stipulated distances from property borders, overhead lines and electrical transmission lines (5-30 m, depending on type).
Telecommunication and Aesthetic Constraints	The blades must not interfere with telecom signals, and the turbines must be matte-finished and devoid of advertising (SEAI, n.d.)

6.2.5.1.4 Generic limitations

Choosing a one-size-fits-all turbine entity for the multitude of energy demands of buildings is unfeasible. The energy use of homes, community centres and small businesses vary widely, meaning that a one-size-fits-all approach is inefficient.(Tom, 2015)

6.2.5.1.5 Efficiency concerns

Similarly, the most roof-mounted wind turbines are less efficient compared to larger ground-mounted alternatives because their power is diminished by surrounding buildings. The structure induces roof turbulence to lessen the turbine's energy generation potential.(Tom, 2015)

6.2.5.1.6 Environmental concerns

The recent impact of Storm where the high wind speed at Aran Islands highlights the vulnerability of roof-mounted wind turbines in this region. The storm caused extensive damage, including prolonged power outages and infrastructure disruptions. Given the severity of such storms, installing roof-mounted turbines is not feasible due to potential structural risks and safety concerns.

6.2.5.1.7 Conclusion

Due to the structural inadequacies of roofs, regulatory compliance and environmental concerns, roof-mounted turbines are not viable in the Aran Islands.

6.2.5.2 Offshore wind energy resource assessment

In currently in Ireland 79 offshore projects has been planned and only one 25 MW Arklow Bank - phase 1 project has commissioned. (TGS 4C offshore database, 2024) Another way of is communities could negotiate with offshore wind project implementors to purchase or own a share with defining the conditions.

Determining through spatial analysis method suitable area has been estimated. The suitable limits summarized by by Ceoğlu et al has been overview including resource shore depth and legal protected area and availability of substation locations (Caceoğlu et al., 2022).

Table 6.8 Offshore wind suitability limits

Data source: (Caceoğlu et al., 2022)

Criteria	Measure	Value
Resource	Offshore wind speed (100m)	>6.5 m/s
Depth Range	Water Dept (m)	< 100m
Legal protected areas	SPAs, NHAs, SACs	Exclude
Substation location	380–400 kV substation locations needed	-

The data has resourced from the SEAI developed Wind energy database which sourced from New Europe Wind Atlas (New European Wind Atlas, 2019) model developed by Cluster WAsP at 100m. Offshore Wind resource are around 10 m/s indicating sufficient location. By analysing the conservated land is around 5 km range on Inishmaan. In Wave section shore depth and subsea cable locations are detailly explained in Figure 6.46. Additionally, by considering the ship routes previously mentioned in the wave resource assessment should be considered to estimate the suitable area.

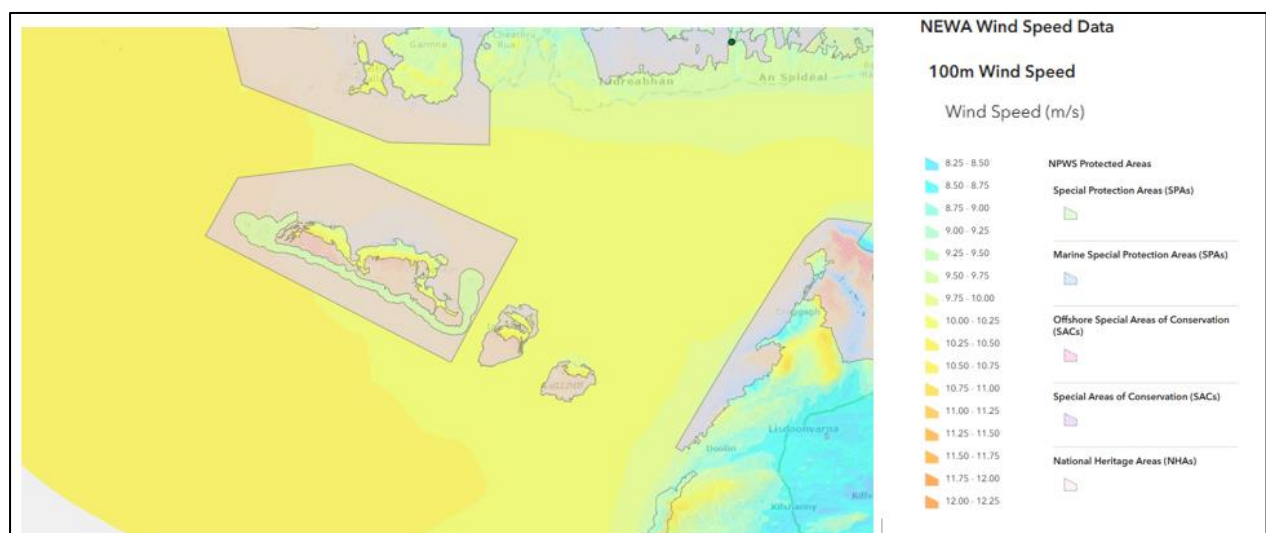


Figure 6.47. Wind speed 100m hub height

Data source: (SEAI, 2024)

6.2.5.3 Tidal energy resource assessment

The metric that is most used in determining areas with an adequate tidal energy resource is the mean peak velocity on spring tides, in m/s, with minimum threshold values for different technology providers starting from a minimum of 1 m/s up to a maximum of 2.5 m/s (O’Connell et al., 2023). The Figure 6.48 below is the available range of mean peak velocity on spring tides (m/s) around Aran Island, with a minimum of 0.1 m/s and up to a maximum of 0.36 m/s. Based on the minimum threshold limitation outlined above, there would appear to be no feasible tidal resource potential around the Aran Islands using existing technology generation.

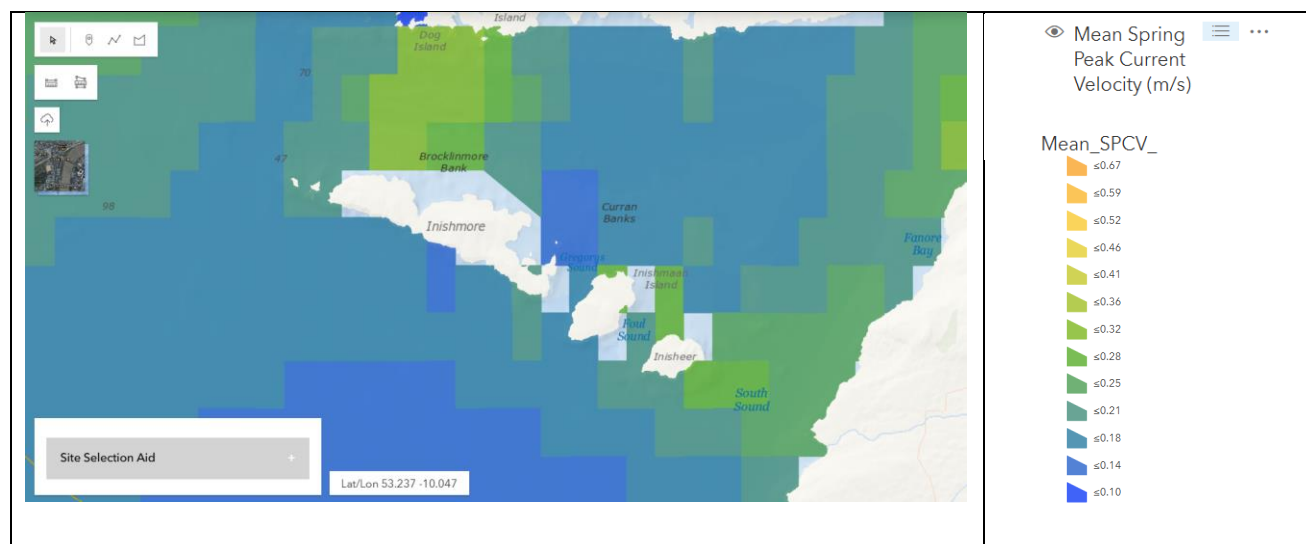


Figure 6.48. Mean peak current velocity on spring tides (m/s).

Source: Selkie Project Web-Based GIS (HORGAN, 2020)

6.3 Renewable energy technologies economic analysis

Table 6.9. Parameters for all RE technologies

Parameters	Units	Value	Source
Solar Park			
Solar PV Capacity	kW	1,000	-
Capital Investment Cost	EUR/kW	1,147	(Turner et al., 2018)
Operation & Maintenance Cost	EUR/kW/Year	16	(Turner et al., 2018)
Decommissioning Cost	EUR/kW	352	(Curtis et al., 2021)
Period of Operation	Years	20	-
Solar Rooftop including Battery			
Solar PV Capacity	kW	4	
Capital Investment Cost	EUR/kW	2,340	
Operation & Maintenance Cost	EUR/kW/Year	67.34	
Decommissioning Cost	EUR/kW	300	
Period of Operation	Years	20	
Wind			
Wind Turbine Capacity	kW	2,350	(Enercon, n.d.-a)
Capital Investment Cost	EUR/kW	1,915	(Baringa, 2018)
Operation & Maintenance Cost	EUR/kW/Year	66	(Baringa, 2018)
Decommissioning Cost	EUR/kW	364	(Tractebel, 2024)
Period of Operation	Years	20	-

Wave			
Wave Project Capacity	kW	5,250	(HORGAN, 2020)
Capital Investment	EUR/kW	19,780.35	
Operation & Maintenance Cost	EUR/kW/Year	119.80	
Decommissioning costs	EUR/kW	356.00	
Period of Operation	Years	20	(Pennock et al., 2022)
Annual Discount Rate	%	4	(DOPE, 2025)

Table 6.10. NPC for all RE technologies

NPC	Value	Units
Solar Park		
Net present Cost of Solar Energy Project (1MWp)	1,549,033.28	EUR
Solar Rooftop including Battery		
Net present Cost of Solar Energy Project (4kWp)	14,053.10	EUR
Wind		
Net Present Cost of Wind Energy Project	7,201,532.98	EUR
Wave		
Net present Cost of Wave Energy Project	108,252,956.51	EUR

Table 6.11. LCOE for all RE technologies

LCOE	VALUE	UNITS
Solar Park		
NPV of total costs	1,549,033.28	EUR
NPV of total energy output	11,518,167	EUR / kWh
LCOE in EUR cents	13	EURc / kWh
Solar Rooftop including Battery		
NPV of total costs	14,053.10	EUR
NPV of total energy output	53,144.00	EUR / kWh
LCOE in EUR cents	26	EURc / kWh
Wind		
NPV of total costs	7,201,532.98	EUR
NPV of total energy output	108,127,682	kWh
Levelized cost of energy	0.06	EUR / kWh
LCOE in EUR cents	6	EURc / kWh
Wave		
NPV of total costs	108,252,956.51	EUR
NPV of total energy output	376,527,311	kWh
Levelized cost of energy	0.29	EUR / kWh
LCOE in EUR cents	29	EURc / kWh
Wave with Innovation funds		
NPV of total costs	66,714,205.31	EUR
NPV of total energy output	376,527,311	kWh
Levelized cost of energy	0.18	EUR / kWh
LCOE in EUR cents	18	EURc / kWh