Empowering local renewable energy communities for the decarbonisation of the energy systems

D4.1 – KPI-driven evaluation framework and baseline

09 June 2023

This project has received funding from the European Union's Horizon 2020 Programme under the Grant Agreement no. 957819

Project Acronym	**LocalRES**				
Project title	Empowering local renewable energy communities for the decarbonisation of the energy systems				
Grant Agreement No.	957819				
Project Duration	48 months	**Start date**	01/05/2021	**End date**	30/04/2025
Work Package	WP4 - Demonstration of LocalRES solutions				
Task	Task 4.1 - Demonstration actions KPIs definition and baseline studies				
Deliverable No.	D4.1				
Deliverable title	KPI-driven evaluation framework and baseline				
Dissemination Level	**PU (Public)** / CO (Confidential)				
Lead beneficiary	FLEXENS		**Deliverable author**	Niko Korpela	
Contributing beneficiary(ies)	FLEXENS, CARTIF, RINA-C, R2M, BARRIZAR, TECNALIA, AIT, GRIDABILITY, KÖKAR, OLLERDORF, AIGUASOL		**Deliverable co-author**	Edvard Nordlund Åsa Hedman Rolf Eriksson Ron Ablinger Michael Niederkofler Simona D'Oca Sara Ruffini Estebe Garcia Iñaki Gaztelu Hernáiz Alberto Belda	
Due date	30/04/2022		**Version date**	09/06/2023	
Status	Working version / Under revision / **Final version**				
Description	A dedicated methodology for the evaluation of the LocalRES demonstration actions is carefully elaborated to quantify the operation and impact of the demonstration actions and the LocalRES software solutions. A set of Key Performance Indicators (KPIs), including both high-level indicators that give information on the development of the whole demonstration area and solution-specific indicators that describe the improvements on more specific attributes, have been developed in line with those described in Task 1.2 and address technical, environmental, economic, and social aspects. This deliverable also includes baseline studies for each of the demonstration sites to set the basis for quantifying the obtained impact of the implemented demonstrations. Apart from the quantitative assessment related to KPIs, the baseline definition in this				

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	task will also provide WP1 with local specific information and data that will be used in the definition of the use cases and their assessment. This deliverable also operates in close collaboration with WP2, where the planning tool KPIs must be aligned with those defined here.

Date	Version	Author	Comment
07/03/2022	V1	Niko Korpela	First draft
19/04/2022	V2	Edvard Nordlund	Structure overhaul
25/04/2022	V3	Niko Korpela	First finished draft ready for review
02/05/2022	V4	Niko Korpela	Modified based on Alberto's comments
13/05/2022	V5	Niko Korpela Edvard Nordlund	Modified based on the 1st peer-review
23/05/2022	V6	Niko Korpela Edvard Nordlund	Modified based on the 2nd peer-review
21/09/2022	V7	Niko Korpela	New version after final review
11/10/2022	V8	Niko Korpela	Consolidated version (first submitted version)
09/06/2023	V8.1	CARTIF	Revised version

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Executive summary

This deliverable, which constitutes the project milestone MS6 (*Evaluation framework and baseline*), starts by defining a KPI-based evaluation framework to capture the achieved impacts once the implementation is complete, which uses as a basis the set impact targets for each demo. In accordance with the Grant Agreement (GA), the KPIs consider technical, environmental, social, and economic aspects:

The technical KPIs are:

- TE1 – Peak electricity demand [MWh/h]
- TE2 – Energy consumption [MWh/a]
- TE3 – Number of ICE vehicles per capita [#]
- TE4 – Number of EVs per capita [#]
- TE5 – Cumulative ESS capacity [%]
- TE6 – Electricity import [%]
- TE7 – Renewable electricity self-production [%]

The environmental KPIs are:

- EN1 – Energy-related emissions [t_{CO2eqv}/a]
- EN2 – Land use for energy [m^2/MW]
- EN3 – Noise level [0 = None/ 1 = Low/ 2 = Medium/ 3 = High/ 4 = Very high]
- EN4 – Visual impact [0 = None/ 1 = Low/ 2 = Medium/ 3 = High/ 4 = Very high]

The social KPIs are:

- SO1 – Citizen engagement [%]
- SO2 – Employment rate [%]
- SO3 – Regulatory REC barriers [None/Partial/Full]
- SO4 – Energy poverty [%]

The economic KPI is:

- EC1 – Share of annual investments towards RES [%]

After evaluation framework is defined, the four project demonstration sites in Finland, Italy, Spain, and Austria will be introduced by providing baseline studies, to further focus on the current status of energy sectors:

For the Kökar demo in Finland, it was found characteristic that the rural community is located in the harsh weather conditions of the Baltic Sea and is very small in size. These characteristics lead to a situation where the community has become reliant on imported energy in the form of sea cable and fossil fuel imports to cover its energy demand, which is especially high during the cold Nordic winter. The LocalRES project is working to change the situation by introducing innovative, flexible, and clean energy solutions to the community, thus improving its self-sufficiency while preventing the energy costs from getting to an unsustainable level. Moreover, the island will get its first public electric vehicle (EV) charger to support the needs of locals and tourists, which is one of the main sources of income int the island.

The demonstration in Italy takes place on the island of Sardinia in a rather small village called Berchidda. The village is characterised by its mountainous surroundings and neoclassical & Art Nouveau building base. The typical house is heated by biomass or diesel-fired boiler and might have battery storage and solar photovoltaics (PV) system installed on its roof already. In the demonstration, heating with heat pumps will be piloted together with smart energy management systems in order to create a Renewable Energy Community (REC) that will increase the role of renewables and decrease the energy bills for the community members. Additionally, several EV chargers will be installed in the village to boost the electric vehicle use in the area.

The Spanish demo site in Ispaster's central neighbourhood called Elexalde disposes already of a solar PV-powered microgrid and a biomass-fired district heating (DH) network in operation. A typical house gets its heating and Domestic Hot Water (DHW) from Liquified Petroleum Gas (LPG) and electricity from the grid. The demonstration action in Ispaster will expand the DH network and install more PV and battery storage capacity in the community to reduce its fossil fuel use and emissions. Additionally, the town will introduce an electric vehicle and EV charger to demonstrate emission-free traffic as well.

The fourth demonstration site, located in the village of Ollersdorf in Austria, is a true front runner in publicly led energy transition. Although the heating sector still relies upon fossil fuels, the town has a decade worth of experience in promoting green energy solutions for its citizens, which has led to around a 20% adoption rate of solar PV systems. From this base, the demonstration actions will include smart ICT-system implementation in order to form an official energy community, where the full advantage is taken from the renewable energy assets. This is achieved via control algorithms and blackout strategies that will be defined in the LocalRES project.

The baseline studies for each of the demo sites include the KPIs calculated for the baseline scenarios. The data collection performed to calculate these KPIs followed a predetermined methodology, where only official sources were used when the measurement could not be done by the partners. Furthermore, the data collection was done in collaboration with Work Package 1 (WP1) of LocalRES for most parts, and the rest was acquired by interviewing local experts and via a survey that was distributed to the demonstration areas.

At the end of the LocalRES project, the data collection will be conducted once again, and then the baseline scenario and the end result will be compared following the evaluation framework defined in section 2/ of this document in order to capture the achieved impacts and assess the different demonstration actions on those bases.

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List of acronyms and abbreviations

$CO2_{eq}$	Carbon Dioxide Equivalent greenhouse gas
DSO	Distribution System Operator
DHW	Domestic Hot Water
ESS	Energy Storage System
EV	Electric Vehicle
GA	Grant Agreement
GHG	Greenhouse Gas
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
KEM	Klima und Energie Model
KPI	Key Performance Indicator
LPG	Liquified Petroleum Gas
LV	Low Voltage
MEVPP	Multi-Energy Virtual Power Plant
ML	Medium Voltage
P2H	Power-to-Heat
PV	Photovoltaic
REC	Renewable Energy Community
RES	Renewable Energy Source
SAIDI	System Average Interruption Duration Index
SME	Small and Medium-sized Enterprises
UPS	Uninterruptible Power Supply
VRES	Variable Renewable Energy Source
WP	Work Package
ÅEA	Ålands Elandelslag (DSO)
ÅSUB	Åland's Centre of Statistics

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1/ Introduction

The LocalRES project will deploy innovative local energy systems driven by Renewable Energy Communities (RECs) for a socially fair energy transition that puts renewable energy into the hands of communities and people. The focus of LocalRES is on Renewable Energy Communities (RECs), introduced by the Clean Energy Package, as key actors to lead the structural change towards the decarbonisation of the local energy systems through the involvement and awareness-raising of citizens and communities. LocalRES will develop a Planning Tool to enable citizen participation in the REC planning decision-making processes and a Multi-Energy Virtual Power Plant (MEVPP) approach to optimise in real-time different energy vectors and different energy and flexibility services provided by the REC according to their community preferences.

LocalRES includes four demonstration cases in remote communities across Europe, where the LocalRES concept will be deployed, and innovative local energy systems with a sector-coupling approach will be demonstrated. The systems will be able to interconnect and optimise the joint operation of different energy vectors (electricity, heating, mobility) by maximising the contribution of Renewable Energy Sources (RES) and enhancing the energy system flexibility and security of supply.

This document introduces the four LocalRES demonstration sites in Finland, Italy, Spain and Austria, providing baseline studies for each location. In addition, this document provides a summary of the task-group-defined KPIs and insight into how they are measured to create an evaluation framework for assessing the impacts of the demonstration actions.

1.1. Purpose & Objectives

This document aims to act as a manual for the upcoming impact assessment of the project after the monitoring period and constitutes a project milestone (MS6, *Evaluation framework and baseline*). In addition, it gives the reader a sufficient image of the demonstration sites before the deployment of the LocalRES project, thus giving context for the evaluation. This deliverable aims to enable transparency in the research and monitoring process.

1.2. Scope of work

The scope of this deliverable is limited geographically to the four demonstration locations: Kökar in Finland, Berchidda in Italy, Ispaster in Spain, and Ollersdorf in Austria. Moreover, the content focuses on the energy sector due to the nature of the project. However, the evaluation framework included in this document will inspect the demonstration actions through technical, environmental, social, and economic lenses, aiming to capture the complete cross-section of the societies involved. From this evaluation framework, high-level and specific indicators and requirements for monitoring relevant parameters can be obtained. Timewise, the scope is limited by the beginning and the end of the project, i.e., May 2021 to April 2025.

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1.3. Relation to other activities of the project

Apart from the quantitative assessment related to KPIs, the baseline definition in this deliverable will also provide WP1 with local-specific information and data that will be used in the definition of the use cases and their assessment. This task also operates in close collaboration with WP2, where the planning tool KPIs must be aligned with those defined here. Finally, this task is strongly connected with all tasks of WP4, where the planning, deployment and assessment of actions in all four demonstration sites are included.

Table 1: Relation of the current report to other deliverables

Deliverables	Relation
D1.2. - Definition of the Use Cases	Strongly connected KPIs are used to those defined in this document.
D2.6. - Assessment module for decision-making	Related but independent KPIs are used to the ones defined in this document.
D3.6. - Blackstart/ islanding mode security provisions	The KPIs defined in this document are keys to describing the preparation of a Renewable Energy Community (REC) for blackouts.
D4.7.- Impact assessment of LocalRES demonstration actions	The impacts measured in the deliverable D4.7 are obtained using the evaluation framework provided in this deliverable.

Table 2: Relation of the current report to other tasks

Tasks	Relation
Task 1.1.– Regulatory assessment	The findings of this task are utilised in obtaining the KPI regarding the regulatory barriers for each demo site.
Task 1.2.- Definition of REC-driven services and Use Cases	The KPI definition and related data collection process were coordinated together between Tasks 1.2 & 4.1 and carried out by AIT.
Subtask 2.4.3.- KPI-driven assessment module for decision making	The KPIs used in subtask 2.4.3 will be related to those defined in T4.1 and T1.2 yet independent. They will include similar information related to technical, environmental, social, and economic aspects.
Task 3.6.- Blackout recovery strategies	A set of blackout strategy-related indicators that are considered in T4.1 will be used to meet the basic requirements of blackout preparation and recoverability.
Task 4.2.– Detailed demonstration planning	Detailed demonstration plans are created for the demo actions described in this deliverable.
Task 4.3.– Field demonstration actions and data monitoring	The demo actions described in this deliverable are implemented and data monitoring commenced.

Task 4.4.– Technical validation of the MEVPP and demonstration actions	Once all the demonstration actions have been implemented it is needed to guarantee that the operation of the new assets fulfil the technical objectives in their isolated operation and when connected in the demo site energy system. In this sense, validation of the MEVPP operation in the demos is one of the key points of this task.
Task 4.5.– Impact evaluation of demonstrations	The impacts of the demo actions are evaluated by comparing end result with the baseline situation, utilizing the framework provided in this document.

Finally, it is worth mentioning the strong relation between this task and the demonstration actions, which are to be deployed, monitored and evaluated in the rest of the WP4 tasks. Thus, despite Task 4.1 focuses on the baseline scenarios and the evaluation framework, an especially strong connection exists between these tasks and besides the iteration of the deliverable with other tasks the KPIs constitute a tool to measure the impact of a specific intervention in a demo site. Therefore, the task and KPIs are related to the demonstration actions. In the following table, the demonstration actions are described. In section 2/, each KPI will be related to the action number, whenever possible.

Table 3: List of demonstration actions planned in each of the demonstration sites

No.	Demonstration action
	1 – Kökar demonstration site
1.1	**Contribution to Åland sustainability Agenda** by reducing CO_2 emissions and increasing the RES share
1.2	**Community engagement**
1.3	**Renovation of the school's heating system**, from an oil-based system to a **hybrid heating system** including thermal storage, heat pumps and micro-wind
1.4	**Solar panels for the school**
1.5	**Micro-wind system for the school**
1.6	**Smart energy management system for the school and demo households**
1.7	**Public charging station for EVs**
1.8	Solar PV system, battery storage and smart EMS in the **Elderly (nursing) home**
	2 – Berchidda demonstration site
2.1	**Community engagement**
2.2	**Energy storage** with optimised community logic
2.3	**E-mobility**, by installing EV infrastructure with Vehicle-To-Grid (V2G) capabilities
2.4	**Uptake of RES**: potential installation of PV, wind turbine, heat pumps
2.5	**Smart management of the distributed energy sources**
	3 – Ispaster demonstration site
3.1	**Community engagement**
3.2	**Upgrade of the DHN and connection of new customers**
3.3	**Expansion of the micro-grid** through the installation of new PV
3.4	**E-mobility** through the installation of EV-charging infrastructure and the purchase of an EV

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3.5	**Power to heat in residential buildings**, replacing existing fuel-based systems
3.6	**Electric storage**
3.7	**Smart control, monitoring and management**
3.8	**Policy recommendations**, in social acceptance, financial or regulatory issues
3.9	**Business model innovation**
	4 – Ollersdorf demonstration site
4.1	**Community engagement**
4.2	**Implementation of smart ICT infrastructure** for the smart operation of the local energy system
4.3	**Implementation of control algorithms and blackout strategies**
4.4	**Community information system**
4.5	**Blockchain based P2P trading / accounting**
4.6	**Future energy scenario and impact of scaling up**

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2/ Key Performance Indicators methodology

This chapter focuses on the evaluation methodology for the LocalRES demonstration activities, namely, on the definition of the theoretical framework for the KPIs that have been selected to assess the different actions in LocalRES demo sites. The chapter is divided into four different subchapters which correspond to each of the KPI categories: technical, environmental, social and economic. Within each of these subsections, each of the KPIs included in the associated category is presented, differentiating two parts: description and evaluation framework. Additionally, at the end of the chapter, a fifth subchapter summarizes all the selected KPIs.

KPI DESCRIPTION

For each of the selected KPIs, the background and usage of each indicator are explained. The aim is to give the reader a full understanding of what type of information they consist of and why these specific KPIs were selected as the basis of evaluation for LocalRES. The KPI values associated with the baseline scenario are needed in modelling and other studies to form a solid foundation for the evaluation framework used to assess the achieved impact of the LocalRES project compared to the expectations. The KPIs will be defined to assess the demos at the site level and also depending on the specific intervention that is going to be installed (e.g., PV on rooftops).

EVALUATION FRAMEWORK

For every KPI, a customised evaluation framework is defined to review the demonstration actions across the demo sites, including instructions about how the data for the KPIs should be collected and how the KPI should be measured, monitored and/or calculated. In all cases, one or more formulas are included with defined variables, to assess how the KPIs initial values (i.e. before LocalRES), change after the actions performed in LocalRES project.

As a general rule, the required data must be monitored or collected from official and trusted sources, such as local DSOs, energy companies and statistical centres. If such sources are not available, N/A is to be marked. For qualitative data, formally drafted structured interviews shall be utilised to keep the data uniform. Structured interviews are, essentially, verbally administered questionnaires. A list of predetermined questions is asked, with little or no variation and no scope for follow-up questions to responses that warrant further elaboration. Consequently, they are relatively quick and easy to administer and may be of particular use if clarification of specific questions is required or if there are likely literacy or numeracy problems with the respondents. The questionnaire that was distributed to evaluate some of the KPIs for the baseline scenarios can be reviewed in the annexes at the end of this document.

Due to the lack of measurements, accuracy and protection policies for personal data, the KPI data are measured on the community scale in each demo site, i.e., on a village level. Therefore, some parameters might differ from those set in the GA, e.g., considering the impact. However, the measurement accuracy in the KPIs should be sufficient to capture the effects estimated and defined in the GA.

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To assess the quality of the data, five levels have been defined based on the five-star Data Quality System from the EU Building Stock Observatory Database (European Commission). The quality scores for the data quality are 1 assumption, 2 literature, 3 model output, 4 official statistics or data gathered from surveys to citizens and local stakeholders, and 5 actual monitoring data or calculations based on monitored data. This system allows knowing about the source of the data and its reliability and is applied in each of the sections dedicated to the baseline studies of the demonstration sites.

Some KPIs, marked with *, are collected sector-wise. The remaining KPIs are collected for the demo site. The different sectors are:

- **Residential** – privately owned dwellings and holiday homes
- **Public Services and Spaces** – community-owned buildings such as schools, libraries, city halls, etc.
- **Agriculture** – farms, animal farms, and other food production
- **Transport** – all the transportation forms that are relevant for the given demo site
- **Industry & businesses** – manufacturing, construction, and private businesses

The symbols in the mathematical formulas for the KPIs are named based on the given name of the KPI rather than International System for Units (SI). Furthermore, the following accent marking applies:

$$X = Value\ measured\ before\ implementing\ the\ LocalRES\ demo\ actions$$

$$\hat{X} = Value\ measured\ after\ implementing\ the\ LocalRES\ demo\ actions$$

$$\bar{X} = Indexized\ change\ between\ the\ values\ before\ and\ after\ LocalRES$$

Where X represents a given KPI.

For KPIs sensitive to weather data, such as electricity consumption concerning outdoor temperature, irradiation data concerning solar PV production, and wind speeds concerning wind power production, a disclaimer is stated for the KPI in question. For these KPIs, a separate sensitivity analysis is required to ensure the comparability of results. Each subsection describes how to perform KPI-specific sensitivity analyses when needed. Both values should be documented for each KPI requiring a sensitivity analysis since there will always be simplifications made when affecting the values between two different weather years. Both the original KPI evaluation and the one including the impact from weather years should be considered in the analysis.

All KPIs are measured annually. The data collector is the Demo Leader from the given demo site by default. The year 2017 has been selected as the base year as it is old enough that the data should be available, as there is usually a lag of a year or two in the publications from statistic institutes. Still, it is also recent enough to be considered relevant.

Finally, it is noteworthy that external factors (e.g., climate change, COVID19, energy crisis) are expected to affect the economic and social indicators, so they may not follow any natural trend, understood as business-as-usual evolutions in last decades. Therefore, the value must be interpreted with caution and awareness of the global situation.

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2.1. Technical KPIs

2.1.1. T1 - Peak Electricity Demand

DESCRIPTION

Highest hourly demand for electrical generation output in the user-side of the demo area during the measuring year. Measured in megawatt-hours per hour.

This KPI was selected as the maximum peak load of a power system is an essential parameter in all societies, especially rural ones. The peak load provides the maximum hourly demand that the system will need to cover at any given time. Since the line feeding the community need to be able to cover the demand peak although it occurs only at a fraction of the time, the lines are over-sized and less cost-efficient. Reducing the peak would improve this situation. However, it is not possible to include thermal energy demand and therefore a major part of the overall peak final energy demand is missing. In addition, it is noteworthy that power-to-heat solutions (e.g. heat pumps) can lower the total final energy demand, while increasing the peak demand for electrical power.

EVALUATION FRAMEWORK

The value should be collected from the local DSO or similar stakeholders with access to these data (e.g., energy trading company, energy utility) whenever possible. Data is collected for a one-year interval, and the peak demand value is the highest recorded. If an electricity meter is installed, the instantaneous power value could be alternatively measured, from which the peak power electricity demand can be obtained. In that case, the peak electricity demand would be measured using a power unit, i.e., megawatt (MW).

Formula:

$$\bar{P} = \frac{\hat{P} - P}{P}$$

Being:

$$P = \frac{P_{max} * h}{h} / annum$$

Table 4: Variables associated with the KPI 'Peak electricity demand'

Variable	Unit	Short description
$\bar{P}$	– [-1..1]	Change in peak electricity demand (per unit; p.u.)
$\hat{P}$	MWh/h	Peak electricity demand (LocalRES)
bP	MWh/h	Peak electricity demand before LocalRES

Sensitivity analysis: in demo sites where electric heating is in place, heating degree days (HDD) (Eurostat, 2020) should be calculated from the historical outdoor temperature in the demo site for the two comparison years. The quotient of dividing the HDD (LocalRES) with the HDD before

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LocalRES allows then factorising the peak electricity demand (LocalRES) variable to include the impact of different weather years, resulting in the following formula:

$$\bar{P} = \frac{\hat{P} \cdot \frac{\widehat{HDD}}{HDD} - P}{P}$$

Where $\widehat{HDD}$ Is heating degree days (LocalRES), and HDD is heating degree days before LocalRES.

For demo sites where comfort cooling is typical, cooling degree days (CDD) (Eurostat, 2020) should be used in the same way, resulting in the following formula:

$$\bar{P} = \frac{\hat{P} \cdot \frac{\widehat{CDD}}{CDD} - P}{P}$$

Where $\widehat{CDD}$ Is cooling degree days (LocalRES), and CDD is cooling degree days before LocalRES.

2.1.2. T2 - Energy Consumption * (T2)

DESCRIPTION

Total final energy consumption (Eurostat, 2018) of the demo area in a year which includes power, gas, other fossil fuels, biomass and heating used by buildings, industry, and transport including all road vehicles. The KPI is measured in megawatt-hours, MWh.

Energy consumption depicts the overall demand for energy per annum and is measured as a difference between two points in time that show an increase or decrease in energy demand during that timeframe. Furthermore, it is measured by sector to gain transparency on the development of each demand in a given society.

EVALUATION FRAMEWORK

As a KPI with sector-specific values, exact figures for each sector should be collected from the local DSO. If the data is not available sector-wise, a total value is used for all sectors combined. Data is gathered for a one-year interval. The same year shall be chosen when collecting the data for the peak electricity demand data.

Formula:

$$\bar{E} = \frac{\hat{E} - E}{E}$$

Being:

$$E = (E_{power} + E_{gas} + E_{heat})/annum$$

Table 5: Variables associated with KPI 'Energy consumption'

Variable	Unit	Short description
$\bar{E}$	– [-1..1]	Change in energy demand [-1..1]
$\hat{E}$	MWh/a	Energy demand (LocalRES)
E	MWh/a	Energy demand before LocalRES

Sensitivity analysis: in demo sites where electric heating is common, calculate heating degree days (HDD) from the historical outdoor temperature in the demo site for the two comparison years. Divide the HDD (LocalRES) with HDD before LocalRES and factorise the energy consumption (LocalRES) variable to include the impact of different weather years, resulting in the following formula:

$$\bar{E} = \frac{\hat{E} \cdot \frac{\widehat{HDD}}{HDD} - E}{E}$$

Where $\widehat{HDD}$ Is heating degree days (LocalRES), and HDD is heating degree days before LocalRES.

For demo sites where comfort cooling is common, cooling degree (CDD) days should be used in the same way resulting in the following formula:

$$\bar{E} = \frac{\hat{E} \cdot \frac{\widehat{CDD}}{CDD} - E}{E}$$

Where $\widehat{CDD}$ Is cooling degree days (LocalRES), and CDD is cooling degree days before LocalRES.

2.1.3. T3 - Number of Internal Combustion Vehicles (ICEs) per capita

DESCRIPTION

Amount of internal combustion engine vehicles registered in the demo area divided by the population, and measured as a number.

The number of ICE vehicles per capita was selected to create a view of ICE's role in CO_2 emissions in a given area and determine the potential of vehicle decarbonisation. The idea is also to cover the local vehicle base to contextualise the KPI about electric vehicles per capita. Furthermore, by dividing the number of vehicles by the population, it is possible to negate the effect of natural change due to population growth/decrease.

EVALUATION FRAMEWORK

The most recent figure from a statistic centre should be used, or if not available, regional averages from official EU data sources should be used instead.

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Formula:

$$\overline{ICE} = \frac{\widehat{ICE} - ICE}{ICE}$$

Table 6: Variables associated with KPI 'Number of ICE vehicles per capita'

Variable	Unit	Short description
$\overline{ICE}$	– [-1..1]	Change in number of ICE vehicles divided by population
$\widehat{ICE}$	– [#]	Number of ICE vehicles (LocalRES) divided by population
ICE	– [#]	Number of ICE vehicles before LocalRES divided by population

Sensitivity analysis: not required.

2.1.4. T4 - Number of Electric Vehicles (EVs) per capita

DESCRIPTION

Number of electric vehicles registered in the national vehicle database in the demo area divided by population, and measured as a number.

The number of EVs per capita is a significant parameter to measure the traffic sector's level of decarbonisation. EVs might reduce the direct exhaust gas emissions and particulate matter; however, the lifecycle emissions of EVs still need to be accounted for when considering decarbonisation. In addition, the amount of EVs is highly relevant from the peak load and power system point of view, as the electric infrastructure might need to adapt to the load from EV chargers. The potential peak power increase will be evaluated in Task 1.3 – *Decarbonisation scenarios assessment under REC*. Furthermore, by dividing the number of vehicles by the population, it is possible to negate the effect of natural change due to population growth/degrowth.

EVALUATION FRAMEWORK

The most recent figure from a statistic centre should be used, or if not available, regional averages from official EU data sources should be used instead.

Formula:

$$\overline{EV} = \frac{\widehat{EV} - EV}{EV}$$

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Table 7: Variables associated with KPI 'Number of EVs per capita'

Variable	Unit	Short description
$\overline{EV}$	– [-1..1]	Change in number of EVs divided by population
$\widehat{EV}$	– [#]	Number of electric vehicles (LocalRES) divided by population
EV	– [#]	Number of electric vehicles before LocalRES divided by population

Sensitivity analysis: not required.

2.1.5. T5 - Cumulative Electric Storage System (ESS) Capacity

DESCRIPTION

Total amount of energy storage capacity connected to the system measured as a share of the peak electricity demand, including batteries, thermal storage, pumped hydro storage etc. UPS (Uninterruptible Power Supply) systems and other private storage are excluded as they are not connected to the grid and thus are not shared by the community.

This KPI aims to capture societies' level of resilience and amount of flexibility resources. This is an important factor for blackout readiness and MEVPP services and an indicator of the volatile renewable capacity that can be deployed and supported. In addition, it indicates community's ability to endure blackouts to some extent.

EVALUATION FRAMEWORK

The number from local energy companies and cumulative total from other users.

Formula:

$$\overline{ESS} = \frac{\widehat{ESS} - ESS}{ESS}$$

Being ESS:

$$ESS = ESS_{tess} + ESS_{bess} + ESS_{phs}$$

Table 8: Variables associated with KPI 'Cumulative ESS capacity'

Variable	Unit	Short description
$\overline{ESS}$	– [-1..1]	Change in cumulative electric storage system capacity
$\widehat{ESS}$	%	Cumulative electric storage system capacity (LocalRES)
ESS	%	Cumulative electric storage system capacity before LocalRES

Sensitivity analysis: not required.

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2.1.6. T6 - Electricity Import

DESCRIPTION

The net amount of transferred power to the area annually, where a negative value indicates net export, and measured as a share of total electricity consumption.

The amount of imported electricity indicates a community's self-sufficiency level, i.e., the balance of production and consumption where only the grid frequency is used to stabilise the local network.

EVALUATION FRAMEWORK

An exact figure of the share of imported electricity to the demo area in comparison to total final energy consumption in form of electricity should be pursued, which is typically acquired from the local DSO. Data is gathered for a one-year interval. The same year shall be chosen when collecting the peak electricity demand data.

Formula:

$$\bar{I} = \frac{\hat{I} - I}{I}$$

Being I the total electricity consumption from the grid.

$$I = \frac{E_{imported}}{E_{total}}$$

Table 9: Variables associated with KPI 'Electricity import'

Variable	Unit	Short description
$\bar{I}$	– [-1..1]	Change in electricity import
$\hat{I}$	%	Electricity imports (LocalRES)
I	%	Electricity imports before LocalRES

Sensitivity analysis: in demo sites where electric heating is in place, heating degree days (HDD) (Eurostat, 2020) should be calculated from the historical outdoor temperature in the demo site for the two comparison years. The quotient of dividing the HDD (LocalRES) with the HDD before LocalRES allows then factorising the electricity imports (LocalRES) variable to include the impact of different weather years, resulting in the following formula:

$$\bar{I} = \frac{\hat{I} \cdot \frac{\widehat{HDD}}{HDD} - I}{I}$$

Where $\widehat{HDD}$ Is heating degree days (LocalRES), and HDD is heating degree days before LocalRES.

For demo sites where comfort cooling is common, cooling degree (CDD) days should be used in the same way resulting in the following formula:

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$$\bar{I} = \frac{\hat{I} \cdot \frac{\widehat{CDD}}{CDD} - I}{I}$$

Where $\widehat{CDD}$ Is cooling degree days (LocalRES), and CDD is cooling degree days before LocalRES.

2.1.7. T7 - Renewable Electricity Self-Production

DESCRIPTION

The total amount of locally produced electricity from renewable sources in a year is measured as a share of overall power consumption.

Once the level of self-sufficiency is known, this KPI indicates the penetration of renewables in relation to the self-production. As the LocalRES project aims to advance the usage of renewable energy, it is essential to know the baseline penetration.

EVALUATION FRAMEWORK

A number calculated as a sum of electricity self-production from renewable sources.

Formula:

$$\overline{RE_{el}} = \frac{\frac{(\hat{S} + \widehat{W} + \cdots)}{\hat{E}} - \frac{(S + W + \cdots)}{E}}{\frac{(S + W + \cdots)}{E}}$$

Table 10: Variables associated with KPI 'Renewable electricity self-production'

Variable	Unit	Short description
$\overline{RE_{el}}$	– [-1..1]	Change in renewable electricity self-production
$\hat{S}$	MWh	Solar PV self-consumed production (LocalRES)
$\widehat{W}$	MWh	Wind power self-consumed production (LocalRES)
S	MWh	Solar PV self-consumed before LocalRES
W	MWh	Wind power self-consumed production before LocalRES
$\hat{E}$	MWh	Total final electricity consumption of demo site (LocalRES)
E	MWh	Total electricity consumption of demo site before LocalRES
$+\cdots$	MWh	Other renewable resources such as biomass-based or hydro power

Sensitivity analysis: The solar PV production variable radiation data for the demo site shall be compared between the two years relevant for the KPI. Available radiation data is summarised over the year (LocalRES) and divided by summarised radiation for the base year before LocalRES. The same approach will be applied for the wind power production variable, but with wind speed data

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instead. The total electricity variable will be factorised with the HDD and/or CDD approach described previously. This results in the following formulas:

$$\overline{RE} = \frac{\frac{\left(\hat{S} \cdot \frac{\widehat{\sum R}}{\sum R} + \widehat{W} \cdot \frac{\widehat{\sum V}}{\sum V}\right)}{\hat{E} \cdot \frac{\widehat{HDD}}{HDD}} - \frac{(S+W)}{E}}{\frac{(S+W)}{E}}$$

And

$$\overline{RE} = \frac{\frac{\left(\hat{S} \cdot \frac{\widehat{\sum R}}{\sum R} + \widehat{W} \cdot \frac{\widehat{\sum V}}{\sum V}\right)}{\hat{E} \cdot \frac{\widehat{CDD}}{CDD}} - \frac{(S+W)}{E}}{\frac{(S+W)}{E}}$$

Where, $\widehat{\sum R}$ is the sum of radiation over the year (LocalRES) in either hourly or daily intervals depending on available data. $\sum R$ is the sum of radiation over the year before LocalRES project. $\widehat{\sum V}$ is the sum of wind speeds over the year (LocalRES) in either hourly or daily intervals depending on available data. $\sum R$ is the sum of wind speeds over the year before LocalRES project.

2.2. Environmental KPIs

2.2.1. EN1 - Energy-Related Emissions *

DESCRIPTION

Annual total carbon dioxide equivalent emissions in the demo sites from energy production, transportation, and energy used in industry, including the imported electricity's carbon footprint. This KPI with sector-specific value is measured in tons of carbon dioxide equivalent greenhouse gasses.

As the number of greenhouse gasses emitted into the atmosphere is one of the main drivers of climate change, it is imperative to know these emissions. Hence, it is also vital for LocalRES to measure the impact of Greenhouse Gas (GHG) emissions to assess the potential of the implemented solutions in reducing them.

EVALUATION FRAMEWORK

A calculated number using the GHG protocols tool and local carbon intensity factors (WRI & WBCSD, 2021).

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Formula:

$$\overline{CO2} = \frac{\widehat{CO2} - CO2}{CO2}$$

Being:

$$CO2 = \sum E_i \cdot f_{GHG,i}$$

Where E denotes the energy demanded per energy carrier i and $f_{GHG,i}$ denotes the emission factor (relating GHG and final energy use), which depends on the country to country and energy carrier i (WRI & WBCSD, 2021).

Table 11: Variables associated with KPI 'Renewable Energy-related emissions'

Variable	Unit	Short description
$\overline{CO2}$	– [-1..1]	Change in energy-related emissions
$\widehat{CO2}$	t_{CO2eq}/a	Energy related emissions (LocalRES)
$CO2$	t_{CO2eq}/a	Energy related emissions before LocalRES

Sensitivity analysis: not required.

2.2.2. EN2 - Land use for energy

DESCRIPTION

The proportional land area occupied by energy production units in the demo area, measured in occupied square meters per generation capacity in megawatts. Space corresponding to rooftop solar is not included, since the land is occupied by the building anyway. Similarly, other energy systems integrated into other elements whose main use is different are not included (e.g. PV on car shelters).

The amount of used land area for energy production is an interesting way to measure the energy density of the used technology. The used space could be occupied by other use, e.g., food production or nature, so it is relevant to know the theoretical trade-off of the energy system. It is important to note that, as there are new non-building integrated production units included in many of the demos and no dismantled old units, the land use indicator is expected to increase.

EVALUATION FRAMEWORK

This KPI can be obtained by using a database of local maps shows the property borders. Only the properties solely dedicated to energy production will count (e.g., rooftop solar is not). For wind turbines, the area is calculated as a circle where the radius is the hub-height, i.e., $A_{wind\ turbine} = \pi * height^2_{wind\ turbine}$.

Formula:

$$\bar{A} = \frac{\hat{A} - A}{A}$$

Being:

$$A = \frac{A_{production}}{P_{production}}$$

Table 12: Variables associated with KPI 'Land use for energy'

Variable	Unit	Short description
$\bar{A}$	– [-1..1]	Change in land use for energy
$\hat{A}$	m^2/MW	Land use for energy (LocalRES)
A	m^2/MW	Land use for energy before LocalRES

Sensitivity analysis: not required.

2.2.3. EN3 - Noise level

DESCRIPTION

The level of energy production-related noise which is audible to humans. The following qualitative assessment criterion has been proposed:

- **None** = non-disturbing, non-audible
- **Low** = non-disturbing and hardly detectible
- **Medium** = non-disturbing but can be heard
- **High** = disturbing
- **Very high** = unbearable

This KPI was selected to gather knowledge of the perceived audial impact of the energy systems, as it can be one the most direct effect on residents' everyday lives.

EVALUATION FRAMEWORK

A value is obtained from the responses to the survey questions number 3 and 4 (see ANNEX I – LocalRES Citizen Survey) according to the following conversion from qualitative options to numeric:

0 - None: Not at all; I'm adjusted to it
1 - Low : A little, it disturbs me seldom
2 - Medium: Quite a bit; it disturbs me frequently
3 - High: A lot, it disturbs me most of the time
4 - Very high: Too much, the sound is unbearable

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Formula:

$$\overline{N} = \widehat{N} - N$$

Table 13: Variables associated with KPI 'Noise level'

Variable	Unit	Short description
$\overline{N}$	– [-4.. 4]	Change in noise level
$\widehat{N}$	– [None= 0/ Low= 1/ Medium= 2/ High= 3/Very high= 4]	Noise level (LocalRES)
N	– [None= 0/ Low= 1/ Medium= 2/ High= 3/Very high= 4]	Noise level before LocalRES

Sensitivity analysis: not required.

2.2.4. EN4 - Visual impact

DESCRIPTION

The level of visual discomfort from the energy production units according to consensus. The following qualitative assessment criterion has been proposed:

- **None** = hidden/unnoticeable
- **Low** = hardly noticeable and non-disturbing
- **Medium** = noticeable and non-disturbing
- **High** = disturbing
- **Very high** = unbearable

This KPI was selected to gather knowledge of the perceived visual impact of the energy systems, as it can be one of the most direct effects on residents' everyday lives.

EVALUATION FRAMEWORK

A value was obtained from the responses to the survey questions number 5 and 6 with the following options:

0 - None: Not at all; I'm adjusted to it
1 - Low : A little, it disturbs me seldom
2 - Medium: Quite a bit; it disturbs me frequently
3 - High: A lot, it disturbs me most of the time
4 - Very high: Too much, the sound is unbearable

Formula:

$$\overline{V} = \widehat{V} - V$$

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Table 14: Variables associated with KPI 'Visual impact'

Variable	Unit	Short description
$\overline{V}$	– [-4.. 4]	Change in land use for energy
$\widehat{V}$	– [None= 0/ Low= 1/ Medium= 2/High= 3/Very high= 4]	Visual impact (LocalRES)
V	– [None= 0/ Low= 1/ Medium= 2/High= 3/Very high= 4]	Visual impact before LocalRES

Sensitivity analysis: not required.

2.3. Social KPIs

2.3.1. S1 - Citizen engagement

DESCRIPTION

The share of citizens within the demo involved with the demo actions. [%]

This percentage gives the project group a sense of the level of local motivation and is used to provide a gauge to measure the success of citizen engagement actions.

EVALUATION FRAMEWORK

Calculated as the share of households answering the questionnaire

Formula:

$$\overline{CE} = \frac{\widehat{CE} - CE}{CE}$$

Table 15: Variables associated with KPI 'Citizen engagement'

Variable	Unit	Short description
$\overline{CE}$	– [-1..1]	Change in citizen engagement
$\widehat{CE}$	%	Citizen engagement (LocalRES)
CE	%	Citizen engagement before LocalRES

Sensitivity analysis: not required.

2.3.2. S2 - Employment rate

DESCRIPTION

The employment rate in the demo area, expressed as a percentage.

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The employment rate is a factor that influences a wide range of social characteristics in societies. The rate is used to provide an overall image of the demography and social atmosphere.

EVALUATION FRAMEWORK

Most recent figure from a statistic centre, or if not available, according to local experts.

Formula:

$$\overline{ER} = \frac{\widehat{ER} - ER}{ER}$$

Table 16: Variables associated with KPI 'Employment rate'

Variable	Unit	Short description
$\overline{ER}$	– [-1..1]	Change in the employment rate
$\widehat{ER}$	%	The employment rate (LocalRES)
ER	%	Employment rate before LocalRES

Sensitivity analysis: not required.

2.3.3. S3 - Regulatory REC barriers

DESCRIPTION

The level of regulatory hindering the implementation of the demo actions

- **None** = regulation works as is
- **Partial** = regulation needs modification, or clarifications of regulation are still pending
- **Full** = regulation needs to be changed

This KPI was selected to provide a clear picture of energy communities' regulatory status and whether it has developed during the project's lifetime.

EVALUATION FRAMEWORK

Based on literature review/studies obtained in cooperation with the Task 1.1 of WP1 (see deliverable D1.1 for more details).

Sensitivity analysis: not required.

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2.3.4. S4 - Energy poverty

DESCRIPTION

The proportion of demo area households whose share of energy expenditure over their total income is more than twice the national median share (European Commission, 2020). This KPI is measured in percentage based on the 2M indicator (Johannes Thema, 2020).

The energy poverty KPI is used to create an overall image of the cost efficiency of the energy system in place for the residents in the demo areas and how it will change along with the project. This KPI does not include only the cost efficiency of the demo actions as multiple external factors have significant implications, such as inflation, general energy prices, and international crises and conflicts.

EVALUATION FRAMEWORK

Data is collected through a questionnaire (see Annex I). A value was obtained by comparing survey results to the regional energy expenditure rates to the responses to the survey question number 7 with the following options:

- Less than 5%
- More than 5, less than 10%
- More than 10, less than 15%
- More than 15, less than 20%
- More than 20, less than 25%
- More than 25, less than 30%
- More than 30, less than 45%
- More than 45, less than 50%
- More than 50%
- I don't know / I don't want to answer

Formula:

$$\overline{EP} = \frac{\widehat{EP} - EP}{EP}$$

Being:

$$EP = \frac{responses\ \geq 2 * the\ regional\ median}{total\ number\ of\ answers}$$

Table 17: Variables associated with KPI 'Energy poverty'

Variable	Unit	Short description
$\overline{EP}$	[-1..1]	Change in energy poverty
$\widehat{EP}$	%	Energy poverty (LocalRES)
EP	%	Energy poverty before LocalRES

Sensitivity analysis: not required.

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2.4. Economic KPIs

2.4.1. EC1 - Share of annual investments towards RES

DESCRIPTION

The number of investments in the demo area towards RES as a share of communities' total annual investments, and therefore measured in percentage.

This KPI is used to see if the implemented innovations will cause a wave of investments in renewable energy generation.

EVALUATION FRAMEWORK

The most recent figure from a statistic centre or such, or if not available, interviews local experts.

Formula:

$$\overline{AI} = \frac{\widehat{AI} - AI}{AI}$$

Table 18: Variables associated with KPI 'Share of annual investments towards RES'

Variable	Unit	Short description
$\overline{AI}$	- [-1..1]	Change in share of annual investments towards RES
$\widehat{AI}$	%	Share of annual investments towards RES (LocalRES)
AI	%	Share of annual investments towards RES before LocalRES

Sensitivity analysis: not required.

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2.5. List of selected KPIs

Below, the list of selected KPIs is included (Table 19), also indicating the category, unit, and main demonstration actions expected to affect each of the KPIs, when possible. As can be seen from this assessment, some KPIs will allow evaluating the joint effects of multiple or all actions, while others are only expected to be affected by specific actions. In any case, it is to be noted that this identification between demo actions and KPIs constitutes a preliminary and illustrative exercise only, but the inherent interlinkages of the actions and most of the KPIs are expected to complicate differentiating the separate effects of the demonstration actions in the end.

Table 19: Summary of selected KPIs to evaluate the LocalRES demonstration actions

Category	KPI	Unit	Main demo actions affecting the KPI
Technical	Peak electricity demand	MWh/h	1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 2.2, 2.4, 2.5, 3.6, 3.7, 4.2, 4.3, 4.5
	Energy consumption	MWh/a	1.3, 1.6, 1.8, 2.2, 2.3, 2.4, 2.5, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7
	No. of ICEs per capita	#	1.7, 2.3, 3.4
	No. of EVs per capita	#	1.7, 2.3, 3.4
	Cumulative ESS capacity	%	1.3, 1.8, 2.2, 3.6
	Electricity import	%	1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 2.2, 2.3, 2.4, 2.5, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 4.2, 4.3, 4.5
	Renewable electricity self-production	%	1.2, 1.4, 1.5, 1.8, 2.4, 2.5, 3.3
Environmental	Energy-related emissions	t_{CO2eq}/a	1.1, 1.3, 1.4, 1.5, 1.6, 1.8, 2.2, 2.3, 2.4, 2.5, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 4.2, 4.3, 4.5
	Land use for energy	m^2/MW	1.3, 1.5, 2.4, 3.5
	Noise level	-	1.3, 1.4, 1.5, 1.8, 2.4, 3.3
	Visual impact	-	1.3, 1.4, 1.5, 1.8, 2.4, 3.3
Social	Citizen engagement	%	1.2, 2.1, 3.1, 4.1
	Employment rate	%	1.1, 3.9
	Regulatory REC barriers	-	1.1, 1.2, 2.2, 3.2, 3.8, 4.6
	Energy poverty	%	1.2, 1.6, 2.2, 2.4, 3.2, 3,5, 4.2, 4.5
Economic	Share of annual investments towards RES	%	1.1, 3.8, 4.6

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3/ Baseline studies from the demonstration sites

This chapter includes a set of baseline studies from all the LocalRES demonstration sites, including the values for the selected KPIs for each of the demo sites. These studies were conducted in an attempt to create a solid image of the start situation and give information about the ongoing trends that might affect the results, both in terms of demographical information and energy-related data. The baseline KPIs give the starting point definition of investigated parameters, and the data collection provides the actual values. These values will be compared to ones measured after the implementation of the demo actions in the scope of the project, thus capturing the achieved impact on the system and community. Data collection for the baseline studies from the demo sites was coordinated with the working group of WP1 to utilise synergies and avoid overlapping work as far as possible. The collection was essentially done by first creating a long list of parameters that would be interesting for each WP and then assessing the synergies and plausible methodologies for collecting each. The result was a shortlist of data points distributed collectively to all demo teams that collected and comprised the required data in a single effort, which was then filtered and sorted by AIT, the leader of WP1. Additionally, a survey was sent to the demo area residents to collect their first-hand experiences of the energy system in place and engage them in the project (see a template in ANNEX I – LocalRES Citizen Survey).

3.1. Baseline study of Kökar

Kökar is one of the six self-governed small archipelago municipalities in the Åland Islands, with a total land area of 64 km^2 (total area of 2,165 km^2). The island is located between the cities Turku and Stockholm along some of the main marine routes, as shown in Figure 1. The population of Kökar island is officially 232 persons (2019), but from a political perspective, the island is a full-scale municipality (ÅSUB, 2021). 160-170 persons live on Kökar in the winter, almost 1,000 in the summer, and some 18,000 tourists visit the island yearly. This results in high volatility and puts extra demand on the flexibility of the infrastructure. On winter's day, some 170 people use the island systems, while there can be thousands of users in July (Vainio & Nordlund, 2020). The archipelago municipality's population has been decreasing over the years, and it has fallen to a quarter during the last hundred years, as can be obtained from Figure 2 (ÅSUB, 2021).

Kökar is a small, lively archipelago community with all the basic services of a municipality: a library and a school by the sea, a kindergarten, health services, and a nursing home. The development of the municipality of Kökar is dependent on a vibrant local business. The main economic activities are shipping, agriculture, coast guard, bakery, tourism, and public service. Entrepreneurship and entrepreneurial spirit have improved on Kökar in recent years and increased the interest for young people to move to the island and have given a small positive increasing younger population. There were 33 registered entrepreneurs in 2013, compared with 18 in 2007. Most private entrepreneurs are in tourism, shipping, and agriculture, but a new bakery has also recently opened on Kökar (Vainio & Nordlund, 2020).

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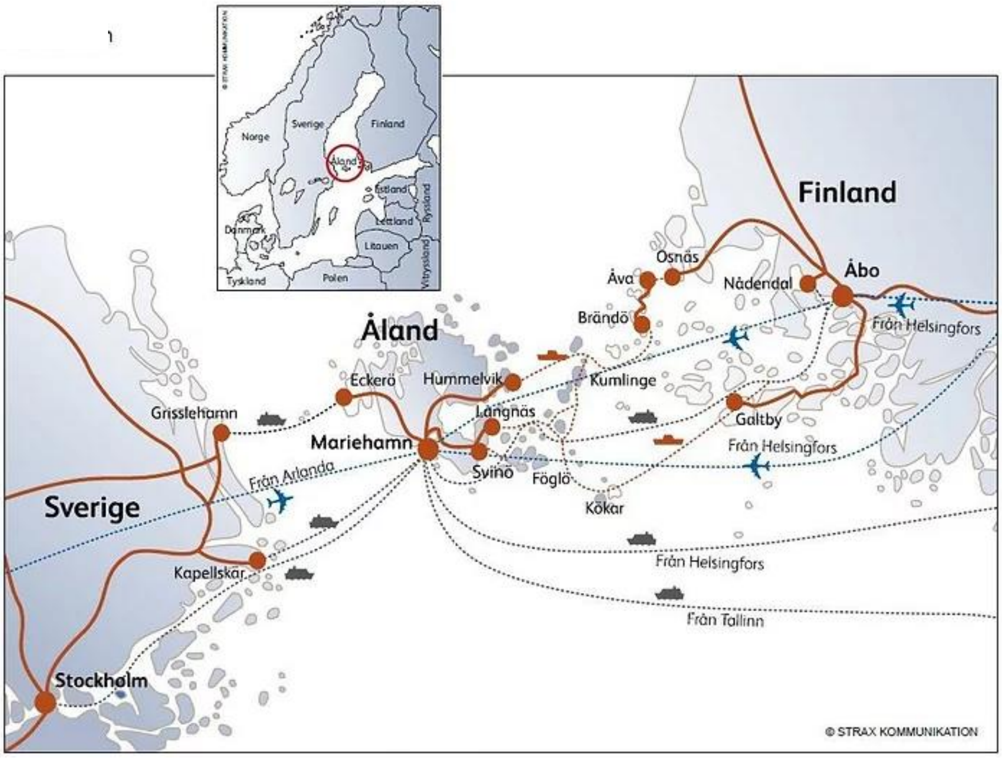

Figure 1: Illustration of the Åland islands' location with Kökar marked (Visit Åland, 2022).

The municipality is Kökar's largest employer, employing about 30 people, most of whom work in day-care, nursing homes, and schools. In the table below, all identified businesses on the island are listed. None of them is exceptionally energy-intensive businesses (Vainio & Nordlund, 2020).

Tourism is an important industry that brings in € 1.9 million a year from 9,000 boat nights, 18,000 overnight stays, and 4,500 day-visitors, who spend € 42 per day on average (boating tourists € 62 per day). There are 227 wage earners on Kökar who, together in one year, earn a total of € 6.3 million, of which € 1.1 million is paid in taxes (Vainio & Nordlund, 2020).

Kökar is connected to the mainland by ferries and an electric and telephone underwater cable. The capacity of the electric cable is 1.5 MW (Kökar-Sottunga-Gustavs). A weak grid connection with occasional outages (3-4 interruptions per year) in the distribution grid causes local energy problems on Kökar. That has been a limitation with the growing reserve generators that need to be taken to the island when there are outages (e.g., the nursing home). The distance to Kökar from the mainland is about 50 km, travelling by ferry (Vainio & Nordlund, 2020).

The final energy consumption is a mix of electricity, oil-based and wood-based resources, adding up to a total consumption of approximately 15,000 MWh annually. Around 7,250 MWh of this is diesel used in ferries to and from the island and makes up most emissions. The annual electricity demand is approximately 3,000 MWh. The demand is supplied by the interconnector and the island's 500 kW wind turbine, producing close to 50 % of the yearly demand. Peak electric load is approximately 800 kW and a minimum of 400 kW. There is an additional 30 kW of micro wind

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turbines and 49 kW of solar PVs. (Vainio & Nordlund, 2020) Based on the decreasing and ageing population trends and energy efficiency measures, the total demand for energy is expected to decrease significantly over the following years.

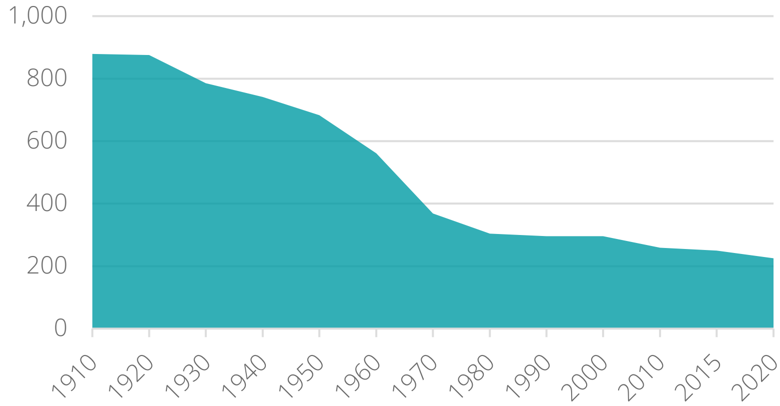

Figure 2: Graph of Kökar's population evolution (ÅSUB, 2021)

Kökar has an ambitious energy transition agenda toward a renewable energy system and a habitability concept developed by Kökar to increase the quality of life on the island (Vainio & Nordlund, 2020).

3.1.1. The baseline of Kökar demonstration buildings

The buildings included in LocalRES, where new installations will occur on Kökar, are the local school in Karlby, a nursing home in Hellsö (see Figure 3 and Figure 4), and approximately 20 private households.

The school in Karlby (Figure 3) is currently heated with light fuel oil with inefficient control that has high saving potential (estimated up to 30%), and electricity is bought from the grid to supply the building's demand. The current oil demand is 240 MWh_{th}/year. In 2021, electricity consumption was 113 MWh/year, with a maximum peak of 27.3 kW and a minimum of 5.4 kW.

Figure 3: Pictures of the Karlby school building

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The school's old oil heating system is the primary heat source and supplies the heat to radiators and a ventilation system to handle the school's indoor climate (a cross-air heat exchanger reduces the heat demand).

The weather conditions during the winter period can be very harsh for the buildings and people with high winds, low temperatures, and high humidity as long as the Baltic Sea is not ice-covered. Thus, it can be critical to maintaining a stable temperature and air quality for the students during the winter period. The oil deliveries are coming on schedule every 3-4 weeks during the winter period.

If the winter period is intense with a lot of thick ice, the ferry transportation will have delays in schedule and sometimes cancel some ferries. The largest electricity peak consumer in the school is the carpentry and welding training room equipment, including the small kitchen. Otherwise, it is the lighting (mainly changed to LED) and electric education equipment.

Figure 4: Sommarängen nursing home

The nursing home in Hellsö (Figure 4) has a 25 kW_{th} ground-source heat pump supplied with grid electricity. The grid also covers the building's general demand. In 2021, electricity consumption was 211 MWh/year, with a maximum peak of 68.2 kW and a minimum of 5.7 kW.

The nursing home is an extra sensitive business where the supply systems need to work well and have a backup in case of malfunction. The nursing home has a backup diesel connected to the building's power station for operation safety for the residents.

During the year in the nursing home, the most significant electric consumption is the large kitchen that supplies the school, nursing home, and kindergarten with food. During the wintertime, the primary electric consumption is the radiator heating system and the ventilation system for preheating the air (a cross air heat exchanger reduces the heat demand).

Additionally, approximately 20 private houses are part of the demonstration actions. These will be houses with installed heat pumps that will complement smart control. The aim is to provide demand response in grid services (theoretical monitoring), energy efficiency increases, and electricity spot price steering to increase savings while maintaining resident comfort.

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All demonstration actions will consider spot price and efficient tariffs to maximise savings and utilise flexible assets for shorter and longer cycles (daily and seasonal). The aim is to increase the self-consumption of renewable production within the building and comply with grid constraints regarding electricity import and export stated by the local Distribution System Operator (DSO).

The main characteristics of the Kökar demo site's baseline and planned actions are summarised in Table 20 below.

Table 20: Main characteristics of Kökar demo site

Main characteristics of the site
Surface: 64 km^2
Population: 232 inhabitants, but high seasonal volatility
Total no. of buildings: ~350 **Buildings directly involved in the demo:** ~22
Energy mix (island level) Electricity • Wind power: ~37% • Imports: ~63%
Energy demand in the demo: Oil energy demanded 49,000 l Heat energy demand • In school: 291 MWh/a • Nursing home: N/A • Households: N/A Electricity energy demand • In school: 90 MWh/a • Nursing home: 185 MWh/a Households: N/A
Project actions: PV, smarter EMS, battery, wind and hybrid system (heat pumps, etc.)

3.1.2. KPIs for the baseline scenario in Kökar

The values to obtain the KPIs of Kökar's baseline scenario are obtained mainly from official sources such as Åland's centre of statistics (ÅSUB), and the local DSO Lands Elandelslag (ÅEA). However, the small size and rural location of the island create some boundaries reducing the granularity of data available, which consequently lower the accuracy of the results. Nevertheless, by the level of detail was deemed accurate enough for the purpose of this document. The non-absolute values are gathered from the inhabitants of Kökar and with the help of the local municipal office. The values for Kökar's baseline scenario are provided in Table 21 below.

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Table 21: Kökar demo site – KPIs for the baseline scenario

Kökar demo site – Baseline scenario				
KPI	**Unit**	**Value**	**Data quality[1]**	**Demonstration action(s) / Comments**
Technical KPIs				
Peak electricity demand	MWh/h	**1.10**	5	1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8
Energy consumption	MWh/a	**14,980**	4	1.3, 1.6, 1.8
Residential	MWh/a	2,532	4	
Public services & spaces	MWh/a	806	4	
Agriculture	MWh/a	N/A	-	Value integrated to 'Industry & business'
Transport	MWh/a	10,355	4	
Industry & businesses	MWh/a	693	4	
No. of ICEs per capita	#	**2.94**	4	1.7
No. of EVs per capita	#	**0.004**	4	1.7
Cumulative ESS capacity	%	**0**	4	1.3, 1.8
Electricity import	%	**60**	5	1.3, 1.4, 1.5, 1.6, 1.7, 1.8
RES electricity self-production	%	**40**	4	1.2, 1.4, 1.5, 1.8
Environmental KPIs				
Energy-related emissions	t_{CO2eq}/a	**3,030**	4	1.1, 1.3, 1.4, 1.5, 1.6, 1.8
Residential	t_{CO2eq}/a	144	4	
Public services & spaces	t_{CO2eq}/a	108	4	
Agriculture	t_{CO2eq}/a	N/A		Value integrated to 'Industry & business'
Transport	t_{CO2eq}/a	2,693	4	
Industry & businesses	t_{CO2eq}/a	46	4	
Land use for energy	m^2/MW	**22,620**	1	1.3, 1.5
Noise level	-	**Low (1)**	4	1.3, 1.4, 1.5, 1.8
Visual impact	-	**Low (1)**	4	1.3, 1.4, 1.5, 1.8
Social KPIs				
Citizen engagement	%	**6.90**	4	1.2
Employment rate	%	**96.26**	4	1.1
Regulatory REC barriers	-	**Partial**	4	1.1, 1.2
Energy poverty	%	**25**	4	1.2, 1.6
Economic KPIs				
Share of annual investments towards RES	%	**0**	4	1.1

[1] Data quality scores: *1 assumption or estimation, 2 literature, 3 model output, 4 official statistics or data from surveys or interviews to citizens and local authorities, 5 actual registers, including monitoring data or calculations based on monitored data*. Scoring system adapted from the system applied in the EU Building Database (https://ec.europa.eu/energy/eu-buildings-database_en).

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3.2. Baseline study of Berchidda

The Italian pilot of LocalRES is located in Sardinia, in the village of Berchidda. Located on the southern slopes of Mount Limbara, in the north of Sardinia's island region, Berchidda is a village with Neoclassical and Art Nouveau houses positioned in a "crescent" shape town (see Figure 5). The municipality land covers approximately 201km^2, and it is located at an average altitude of 300m, surrounded by a wide hilly area in a radius of almost 20km. The anthropic structures, vegetation, and climatic conditions are typical for Sardinia's inland areas, with average temperatures of 15°C. A significant influence on the climate is Lake Coghinas, which increases the humidity throughout the area to the extent that there are thick blankets of fog in some parts of the year. Precipitation is concentrated in the autumn period; there are often heavy storms that can cause severe damage to crops. Berchidda counts 1,792 buildings made of single houses and blocks of flats: over 88% of residential buildings have 1 to 2 floors above ground; buildings with 3 or more floors represent only 12% of the total residential building stock. Almost 50% of the buildings were built before 1961. Over 98% of the buildings are built with load-bearing masonry, mostly made of "cantonetti" (granite portative elements). The use of concrete blocks is quite recent compared to the average age of the houses.

Figure 5: Hill view of the Berchidda Municipality

The Municipality of Berchidda has a population of 2,636 inhabitants (ISTAT data 2021, see Figure 6). A certain decrease in the number of residents can be noticed in the twenty-year period 2001/2021. In 2001, the population was 3,177, while in 2011, it was 2,941. The demographic decrease in the last twenty years is common to all the municipalities of the Gallura hinterland and Sardinia in general, in favour of a corresponding increase in the population of the coastal municipalities (although varying from municipality to municipality), particularly those with a tourist vocation.

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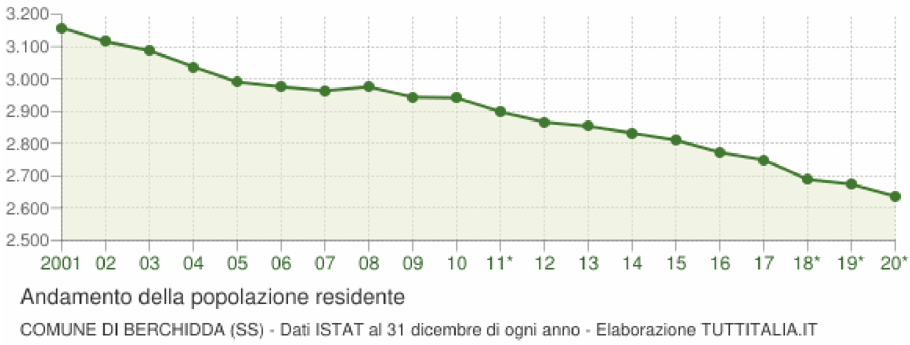

Figure 6: Demographic trend of the resident population in the municipality of Berchidda from 2001 to 2020 (ISTAT, 2022)

Typical Berchidda's residential energy systems include:

- Heating: biomass or diesel-based boilers. Cooling: possibility of individual air-conditioning on a case-by-case.
- DHW: electric or gas boilers controllable with an on/off system.
- Appliances: standard such as lighting, fridges, washing machines, and dishwashers. Cooking stoves and ovens are alimented by gas.

Since January 2021, the municipality has been officially the owner of the electricity grid (ring infrastructure) in both the town centre and the surrounding rural area and serves as the DSO in the form of AEC, the Municipal Electricity Company. The municipality plans to upgrade the electricity grid with smart grid technologies and to promote innovative initiatives along the entire electricity supply chain, involving all stakeholders in the area. The Administration's objectives do not stop at optimising the grid and reducing energy costs for itself and its citizens, but it intends to create one of Europe's first "Local Energy Communities", featuring the possibility to buy and sell energy among citizens, the transparency of electricity metering, which is probed in real-time by both the Administration and the citizen, and the certainty of the data, certified by the municipal grid blockchain.

The main characteristics of the Berchidda's residential power grid (see Figure 7) are presented as follows:

- 17 MV/LV (medium- low-voltage) substations, which are equipped with transformers of varying power between 100 kVA and 500 kVA, for a total power installed of about 5,000 kVA
- 4 km of MV underground cables, 3.2km for the meshed network and 0.8 km for the radial network
- 15.4 km of LV aerial cables
- 21.6 km of LV underground cables

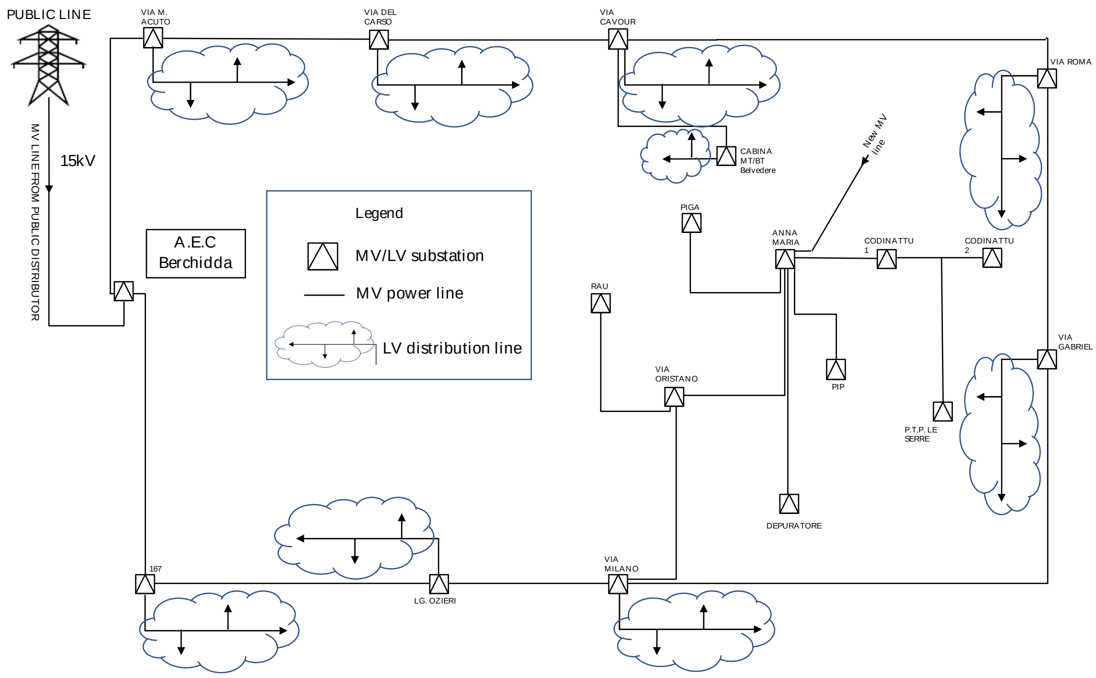

Figure 7: Berchidda residential power grid 4.0

The current aggregated electricity demand for the city of Berchidda is 6,500 MWh, which also includes the energy consumption of around 200 small and medium-sized enterprises (SMEs). The largest part of households' energy demand comes from DHW, lighting, and other specific electric appliances. The average household consumption amounts to 2,436 kWh/year.

The currently existing load curve data, sampled on a 15-minute basis, is owned and saved by the Municipality of Berchidda. Access to this data will be granted to the project pilot partners.

Berchidda counts 87 PV plants (1,000 kWp in total), of which 82 are owned by individual citizens, while the others 5 belong to the local municipality. The PV installations provide around 20% of the electrical energy demand on an annual basis (comparison between the annual energy needs of Berchidda and annual PV generation). The rest of the energy is purchased from the grid. Most of the PV installations existing in Berchidda belong to private homes, which utilise them for instantaneous self-consumption; the surplus of electricity produced is sold back to the grid. The first installation of PV for self-consumption dates to 2011, followed by other installations until today. The development of local PV production has been prompted by individual emulation rather than a collective, coordinated move. Access to PV load curve data will be made possible within LocalRES with the installation of the smart meters and the associated local radio transmitter and gateway. The electric network is owned by the Municipality of Berchidda and operated by AEC - Azienda Elettrica Comunale (Public Energy Office). It is a smart grid, ready for remote management and control, smart billing, and balancing.

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3.2.1. The baseline of Berchidda demonstration buildings

Households will be equipped with fiscal meters owned by the municipality and provided by Landys and NesosNet (the second is part of the GridAbility joint venture). The "EnergyHUB 2.1" smart meter is a modular device, mainly composed of a controller ("Smart Hub") and a three-phase MID-certified (2004/22/EC "Measuring Instruments Directive", 2004) measurement device. The modular device is bidirectional and multichannel (Wi-Fi, LORA, GPRS, BLE). The smart meter provides direct access to load curve data. In order to implement appliance control capabilities in the pilot households, the smart meter needs to be paired with a gateway for communication from/to field devices. The envisioned equipment uses communication protocols Modbus RTU on RS485 serial line or Modbus TCP on Ethernet network. Access and control of meters are managed by NesosNet S.r.l. Within GridAbility, data are stored remotely on a secured cloud platform. Data will be collected through the LoRaWan network owned by the municipality, GPRS and Wi-Fi (where available). The smart meter will act as a transmitter.

20 homes will soon be equipped with individual storage batteries of 5.1 kWh storage capacity each within the HESTIA project.

Within LocalRES Project, the installation of at least 20 domestic heat pumps is foreseen by the end of December 2022. The recruitment of the households for the installations of the heat pumps started in April 2022. A form for the expression of interest for the free installation of 20 heat pumps for heating, cooling and DHW production based on existing or new photovoltaic systems has been circulated. Some mandatory and some rewarding selection criteria have been settled for the household's selection procedure, including:

a) To be resident in the municipality of Berchidda
b) To have a Wi-Fi connection available
c) To have an indoor living space available on a surface not less than 1m x 1m
d) To have certification of the regularity of the electric and heating & cooling systems (Declaration of Conformity)
e) To have the floor plans of the house available
f) To have the technical data sheet of the systems currently present
g) To have the following requirements to take advantage of the rewarding criteria:
    a. The presence or new installation of a photovoltaic system not less than 3 kWp
    b. Presence of air-to-air heat pump (even old generation)
    c. Presence of storage battery

In each of the households where the heat pumps will be installed, a NesosNet smart meter will be connected for continuous data gathering and transmission to the GridAbility secured database.

Around 10 public EV charging stations are envisioned to be installed in the course of 2023. The exact location of these will be evaluated in tandem with the municipality over the next months.

The main characteristics of the Berchidda pilot site's baseline and future installations are summarised in Table 22 below.

Table 22: Main characteristics of Berchidda demo site

Main characteristics of the potential site (entire city)	
Surface: 201 km^2	
Population: 2,636 inhabitants	
Total no. of buildings: 1,792	
Total Electricity demand: 5,762 MWh (data from 2017)	
- Residential: 2,561 MWh	- Non-Residential: 201 MWh
- Public Lighting: 414 MWh	- Commercial/Tertiary: 2,216 MWh
- Industrial: 369 MWh	
Present Renewable Energy Systems: - 87 PV plants (1,000kWp total) (covers ~ 20% of Berchidda's electricity demand)	
Future installations: - 20 residential Energy Storage Systems of 5.1 kWh - 20 residential heat pump systems - 50 NesosNet smart-meter systems - 10 EV Charging Points	

3.2.2. KPIs for the baseline scenario in Berchidda

The values used to obtain Berchidda's KPIs for the baseline scenario are derived from official sources such as municipality reports and scientific articles from UNICA (Cagliari University). More specifically, part of these data were retrieved from the two main articles for the project named "Berchidda 4.0", namely *Planning of a Smart Local Energy Community: The Case of Berchidda Municipality (Italy)* (A. Giordano, 2019) and *Planning of Energy Production and Management of Energy Resources in Local Energy Communities: The Case of Berchidda Municipality (Italy)* (E.Ghiani, 2019). The qualitative KPIs have been obtained from the inhabitants of Berchidda. The values for Berchidda's baseline scenario are provided in Table 23.

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Table 23: Berchidda demo site – KPIs for the baseline scenario

Berchidda demo site – Baseline scenario				
KPI	Unit	Value	Data quality[2]	Demonstration action(s)/ Comments
Technical KPIs				
Peak electricity demand	MWh/h	**1,33**	5	2.2, 2.4, 2.5
Energy consumption	MWh/a	**25,825.43**	5	2.2, 2.3, 2.4, 2.5
Residential	MWh/a	17,234.87	5	
Public services & spaces	MWh/a	3,707.33	5	
Agriculture	MWh/a	0	3	
Transport	MWh/a	4,514.11	3	
Industry & businesses	MWh/a	369,12	3	
No. of ICEs per capita	#	**0.32**	5	2.3
No. of EVs per capita	#	**0**	5	2.3
Cumulative ESS capacity	%	**0**	5	2.2, 2.3
Electricity import	%	**86**	5	2.2, 2.3, 2.4, 2.5
RES electricity self-production	%	**14**	4	2.4
Environmental KPIs				
Energy-related emissions	t_{CO2eq}/a	**1,496.30**	4	2.2, 2.3, 2.4, 2.5
Residential	t_{CO2eq}/a	668.24	3	
Public services & spaces	t_{CO2eq}/a	653.55	3	
Agriculture	t_{CO2eq}/a	0	3	
Transport	t_{CO2eq}/a	91.27	3	
Industry & businesses	t_{CO2eq}/a	83.25	3	
Land use for energy	m^2/MW	**0**	3	2.4
Noise level	-	**Low (1)**	3	2.4
Visual impact	-	**None (0)**	3	2.4
Social KPIs				
Citizen engagement	%	**0.98**	3	2.1
Employment rate	%	**83.53**	4	
Regulatory REC barriers	-	**None**	4	2.2
Energy poverty	%	**14.81**	3	2.2, 2.4
Economic KPIs				
Share of annual investments towards RES	%	**0**	3	

[2] Data quality scores: *1 assumption or estimation, 2 literature, 3 model output, 4 official statistics or data from surveys or interviews to citizens and local authorities, 5 actual registers, including monitoring data or calculations based on monitored data*. Scoring system adapted from the system applied in the EU Building Database (https://ec.europa.eu/energy/eu-buildings-database_en).

3.3. Baseline study of Ispaster

Ispaster is located in the province of Biscay, specifically in the Lea-Artibai region. It is 56 km from the provincial capital, Bilbao, and has very few public transport routes. The municipality halved the number of inhabitants between 1950 and 2000 with 1,105 and 606, respectively (INE, 2022), but the population is increasing since then due to the movement of young families to the town (Figure 8). Currently, Ispaster has a population of around 750 inhabitants living in twelve neighbourhoods. The main district is called Elexalde, a neighbourhood with 350 inhabitants, the site of the town hall, public school, cultural centre, and most of the public services.

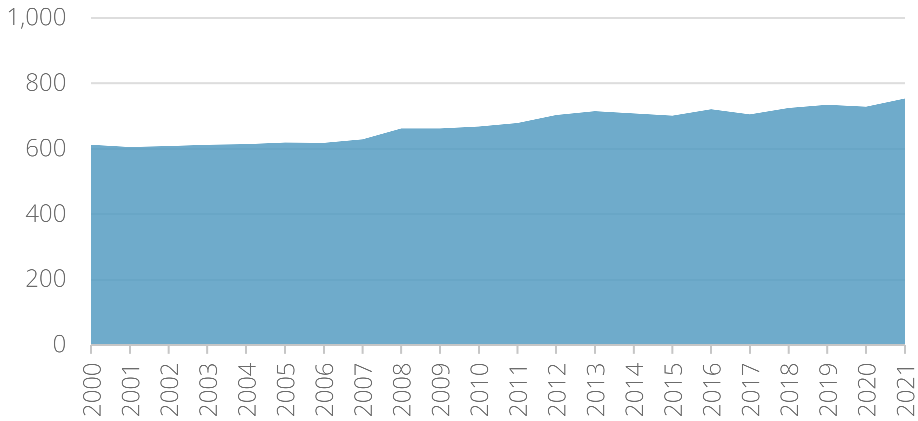

Figure 8: Demographic evolution in Ispaster, 2000-2021 (INE, 2022)

In 2014, the municipality launched a project to generate its own energy and become less dependent on the outside due to its experience with continuous power outages and failures in energy service. Thus, they started a process which nowadays has become two isolated energy islands: a hybrid DH network with 12 consumption points and an isolated micro-grid consisting of PV supported by batteries with 10 consumption points for public buildings.

Two biomass boilers provide most of the thermal energy to the circuit, and solar energy is also used to supplement the boiler's energy input. In this way, by contributing its heat to the return of the primary circuit, the workload of the boiler is reduced, and, in summer, almost the entire demand of the network can be covered without depending on biomass. The network has around 12,000 litres of hot water accumulation (including piping and buffer tanks) and, in 2021 140 MWh of thermal energy were produced for heating and DHW.

This experience in hybridisation and storage has led to a significant reduction in energy consumption of public systems compared to the previous ones based on fossil fuels. In addition, the supply temperature has been gradually reduced (from 80ºC to the current 68ºC), thereby increasing the efficiency of the solar contribution.

The PV microgrid was developed between 2016 and 2019 and has so far installed 28.3kWp. According to current electricity legislation (ITC-BT-40, section 4.1), it is an isolated generating installation, as it is not connected to the grid and relies on battery storage. It also uses 9 inverters

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(5.5 kW each, so a total of 49.5 kW power available) to adapt the current to consumption and 5 regulators to control proper operation. The PV installation produces useful energy of 20,956 kWh per year and has storage that allows about 178 kWh (3 days of autonomy of electric supply without sun).

These small projects show the commitment of the municipal government to make Ispaster a clean and sustainable town and to encourage projects that help in this process. Those projects also contributed to raising the awareness of the people living in the town, who have a clear vision of the benefits of renewable energy technologies. The LocalRES project is being developed in this context, in which the aim is to involve citizens in decision-making and follow the path of renewable energy use and the promotion of efficiency.

As for the economy of the municipality, it is based mainly on the service sector, being the hotel and catering business and commerce the two fundamental pillars of its operation. At the moment, the industry occupies a discreet place with 14% of the total activity, and after it, the first sector is the least developed, based on livestock and agriculture.

3.3.1. The baseline of Ispaster demonstration buildings

As mentioned before, the public DH and microgrid of the town includes several buildings in the main district, Elexalde. Most of them are public, but it also provides energy to private housing. All these buildings connected to the network are highlighted in Figure 9 and Figure 10. Most of the actions of LocalRES project will be directed to these buildings and, therefore, to improve the energy supply of the grid through renewable energies. Currently, about 20,000 kWh of electricity and 140,000 kWh of thermal energy are consumed in the Ispaster's grid every year.

Figure 9: Picture of Elexalde with demonstration building marked.

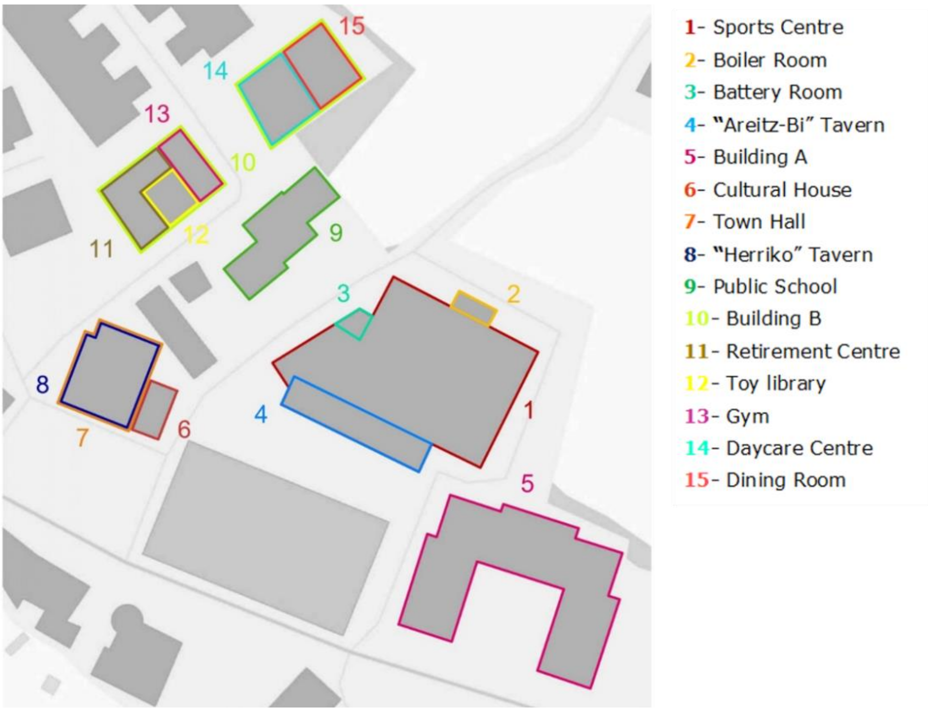

Figure 10: Elexalde blueprint providing identification for the demo buildings.

In addition, three available residential buildings that could be included in the project have been studied. These are buildings that are close to the grid, have the municipality's standard energy equipment and have roofs available for the installation of solar systems if necessary. There is the possibility of supplying renewable energy from the municipal grid or doing it independently, even if they are all part of the same energy community. Figure 11 shows the buildings under study.

Figure 11: Aerial picture of the studied buildings.

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Typical Elexalde's residential energy systems include:

- Heating: LPG based boilers
- Cooling: There are usually no cooling systems installed
- Domestic hot water: LPG-based or electric boilers, controllable with an on/off systems
- Appliances: standard such as lighting, fridges, washing machines, and dishwashers. Cooking stoves and ovens are alimented by gas or electricity

No significant changes either in population or in energy demand have been registered at Elexalde in the last 5 years.

The estimation for the SAIFI (System Average Interruption Frequency Index) average number in Elexalde is 7. The interruptions usually affect the whole district.

Finally, the main characteristics of the Berchidda pilot site's baseline and future installations are summarised in Table 25 below.

Table 24: Main characteristics of Ispaster demo site

Main characteristics of the demo site	
Surface: 22 km^2	
Population: 740 inhabitants	
Total no. of buildings: 36 or 148 dwellings (estimation)	
Total Energy demand: 9,787.80 (data from 2017)	
- Residential: 1,455 MWh	- Agriculture: 48 MWh
- Public services and spaces: 402 MWh	- Transport: 1,542 MWh
- Industrial and businesses: 114 MWh	
Present Renewable Energy Systems: - Micro grid & DH - 2 PV plants (28,3 kWp in total) + Solar Thermal system (42 kW_{th}) - 2 Biomass boilers (210 kW) - 2 Storage systems: Electric batteries (178 kWh) and thermal (13,000 litres)	
Future installations: - 2 EV charging points - Upgrade of current DH to 3 public consumption points - Electric Storage System of 200 kWh - 6 residential heat pump systems - 1 aerothermal system for the Church's heating system - 3 PV Plants (60 kW_e total)	

3.3.2. KPIs for the baseline scenario in Ispaster

The values to obtain the KPIs of Ispaster's baseline scenario were obtained from reliable sources such as the Public Entity for Environmental Management of the Basque Government (IHOBE), the Basque statistic centre (EUSTAT), the electrical DSO Iberdrola, the DSO Repsol for piped propane gas and Barrizar as micro grid & DH energy manager. The rest of the values were gathered from the municipality and people from Ispaster.

Table 25: Ispaster demo site – KPIs for the baseline scenario

Ispaster demo site – Baseline scenario				
KPI	Unit	Value	Data quality[3]	Demonstration action(s)/ Comments
Technical KPIs				
Peak electricity demand	MWh/h	**0.719**	1	3.6, 3.7
Energy consumption	MWh/a	**9,787.80**	4	3.2, 3.3, 3.4, 3.5, 3.6, 3.7
Residential	MWh/a	1,455	4	
Public services & spaces	MWh/a	179	4	
Agriculture	MWh/a	47,8	4	
Transport	MWh/a	7,992	4	
Industry & businesses	MWh/a	114	4	
No. of ICEs per capita	#	**0.37**	4	3.4
No. of EVs per capita	#	**0**	4	3.4
Cumulative ESS capacity	%	**25**	4	3.6
Electricity import	%	**96**	4	3.2, 3.3, 3.4, 3.5, 3.6, 3.7
RES electricity self-production	%	**4**	4	3.3
Environmental KPIs				
Energy-related emissions	t_{CO2eq}/a	**2,942**	4	3.2, 3.3, 3.4, 3.5, 3.6, 3.7
Residential	t_{CO2eq}/a	348.36	4	
Public services & spaces	t_{CO2eq}/a	54.95	4	
Agriculture	t_{CO2eq}/a	15.60	4	
Transport	t_{CO2eq}/a	2,486	3	
Industry & businesses	t_{CO2eq}/a	37.73	3	
Land use for energy	m^2/MW	**10**	4	3.5
Noise level	-	**None (0)**	4	3.3
Visual impact	-	**None (0)**	4	3.3
Social KPIs				
Citizen engagement	%	**3.72**	4	3.1
Employment rate	%	**78.20**	4	3.9
Regulatory REC barriers	-	**Partial**	4	3.2, 3.8
Energy poverty	%	**15.00**	1	3.2, 3.5
Economic KPIs				
Share of annual investments towards RES	%	**8**	4	3.8

[3] Data quality scores: *1 assumption or estimation, 2 literature, 3 model output, 4 official statistics or data from surveys or interviews to citizens and local authorities, 5 actual registers, including monitoring data or calculations based on monitored data*. Scoring system adapted from the system applied in the EU Building Database (https://ec.europa.eu/energy/eu-buildings-database_en).

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3.4. Baseline study of Ollersdorf

The municipality of Ollersdorf, pictured in Figure 12 and Figure 13, is located in the district Güssing (Burgenland province) in South-Eastern Austria. It has about 938 inhabitants and a population density of about 80 inhabitants per km². Ollersdorf is mostly an agrarian region, with no industries settled in the municipality. Tourism also plays a significant role, as the area is known for its hot springs. Hotels that offer spas and golf are an important economic factor in the region, and there are about 100,000 guest nights in the neighbouring municipality.

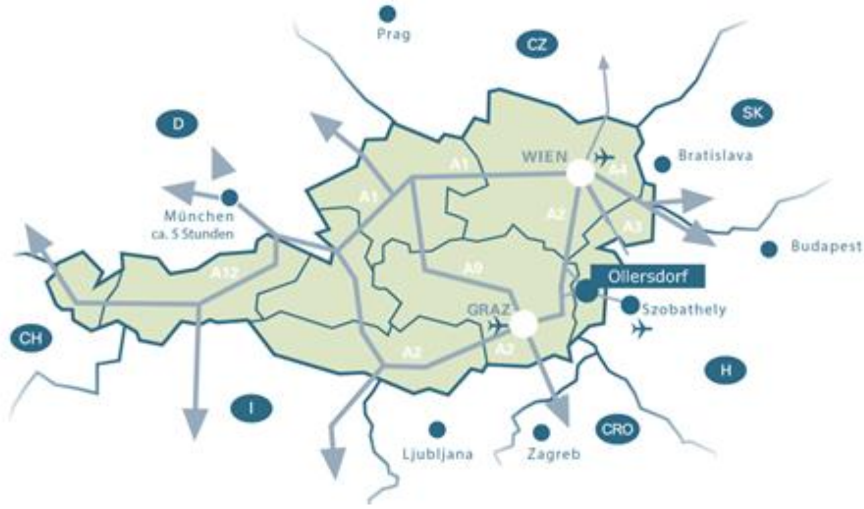

Figure 12: Map of Austria with the location of the municipality Ollersdorf indicated in the south-eastern province of Burgenland

The municipality of Ollersdorf is a part of the Klima und Energie Model Region (KEM) "KEM Golf und Thermenregion Stegersbach". KEM is a program of the Austrian Climate and Energy Fund. Ollersdorf is also a part of the Innovation Lab act4.energy, an initiative of the Austrian Ministry of Transportation, Innovation and Technology in the program "City of Tomorrow". As such, Ollersdorf has a clear strategy to focus on renewable energy and smart municipality.

Figure 13: Overview picture of the municipality Ollersdorf

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Ollersdorf started building up PV capacity about 10 years ago, with about 20% of the households already being equipped with PV installations. The total installed power is currently around 400 kWp, with plans to further increase this capacity. Battery storage was implemented in the town hall in 2019 and is also directly connected to the fire station. This battery supplies the town hall, a doctor's office, and the fire station in case of a blackout. A carport with integrated PV and 5 EV charging stations is also available since 2019.

While the transition towards renewables is already well on its way in the electricity sector, heating still relies on fossil fuels, with oil and gas-fuelled heating systems being very common. The total energy demand is about 26,300 MWh/a with about 7,000 MWh electricity, 5,000 MWh biomass (mostly wood pellets or wood chips heating), 7,000 MWh natural gas and oil (also mostly for heating).

3.4.1. The baseline of Ollersdorf demonstration buildings

Several municipal buildings, as well as private households, will form the core of the REC that is established in Ollersdorf. The municipal buildings will be the town hall, the fire station, the kindergarten, the primary school, the public carport with EV charging points and the local pilgrimage church. There is a small pavilion under construction beside the town hall that will also join the REC once construction is finalised. There is a total of 32 private households that applied to join the REC as well.

Figure 14: Bird view of the municipality Ollersdorf with the participating municipal buildings

Figure 14 shows the bird view of the municipality of Ollersdorf with the participating public buildings. The technical data of the buildings are shown in Table 26. The town hall is equipped with a 14 kWp PV installation, the fire station with a 12.75 kWp PV installation and a 30kWh Na-Ion storage (that is shared with the town hall). The kindergarten is equipped with 6.24 kWp, the primary school is equipped with a 15.25 kWp PV plant and the administration building of the church with a 9.86 kWp PV installation and an 12.52 kWh Li-Ion storage. All of these buildings are also equipped with smart meters provided by the DSO.

Table 26: Main characteristics of Ollersdorf pilot site

No.	Description	Installed assets		
		PV power	Battery capacity	Other
①	**Town Hall** with PV installation on the roof and saltwater battery storage that is shared with the Fire station	14 kWp	-	
②	**Fire Station** with PV installation on the roof and saltwater battery storage that is shared with the Town Hall	12.75 kWp	30 kWh	
③	**Pilgrimage Church** with PV installation on the roof and Li-ion battery storage	9.86 kWp	12.52 kWh	
④	**Kindergarten** with PV installation on the roof	6.24 kWp	-	
⑤	**Primary School** with PV installation on the roof	15.25 kWp	-	
⑥	**PV Carport & Charging** with PV installation on the roof	8.4 kWp	-	
⑦	**Pavilion** with PV installation on the roof and Li-ion battery (under construction)	25 kW (planned)	105 kWh (planned)	
⑧	**Private households** with PV installation on the roof (19 participating, exact location not shown on map)	Installed power between 2.2 – 15.7 kWp	2 households have batteries installed	5 households have heat pumps installed
⑨	**Private households** without PV installation on the roof (13 participating, exact location not shown on map)	None of these households has PV, batteries or heat pumps		
Total number of participating buildings: 39				
The total amount of PV in participating buildings: 205.38 kWp				

Ollersdorf is a small, rural community with most people living in single-family houses. Many of these houses were built before 1990 and are not yet equipped with modern appliances. Typically, this kind of house is heated with oil-fired heating systems, and the domestic hot water is either also provided by the oil-fired boiler or by an electric hot water boiler. Some of these older houses are heated with stoves that are fired with wood logs. These kinds of households typically do have any thermal or electric storage systems and cannot provide flexibility. There are 13 of these

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households participating in the REC. Their exact location is not shown in Figure 14 for data privacy reasons.

More modern houses, especially ones that are built after 2010, typically are very well insulated (although mostly not up to passive house standards) and are equipped with either air-source or geothermal heat pumps. Domestic hot water will also be provided by the heat pump in these households mostly. Electricity is often provided by rooftop PV installations that are also equipped with home battery systems. Some of the modern houses also have modern wood pellet or wood chips heating systems. There are 19 of these households participating in the REC. Their exact location is not shown in Figure 14 for data privacy reasons.

Both building types will be part of the LocalRES projects, with about 10-15 buildings of older type (built before 1990) and about another 10-15 buildings being built after 1990. All the buildings are already equipped with a smart meter that is provided by the DSO. This smart meter data will be the basis for energy accounting within the REC (as required by Austrian regulation).

3.4.2. KPIs for the baseline scenario in Ollersdorf

The values to obtain the KPIs of Ollersdorf's baseline scenario are obtained mainly from public report about Thermenregion Stegersbach (Energie Kompass, 2019) where Ollersdorf is integrated. These data are rescale down based on the share of Ollersdorf´s population in this region. However, to estimated peak electricity demand, monitored date are used to estimate the electricity profile in the municipality and scale up based on the estimated overall electricity demand. The non-absolute values are gathered from direct discussion with the local stakeholders. The values for Ollersdorf's baseline scenario are provided in Table 27.

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Table 27: Ollersdorf demo site – KPIs for the baseline scenario

Ollersdorf demo site – Baseline scenario				
KPI	Unit	Value	Data quality[4]	Demonstration action(s) / Comments
Technical KPIs				
Peak electricity demand	MWh/h	**2.55**	1	4.2, 4.3, 4.5
Energy consumption	MWh/a	**26,109**	1	4.1, 4.2, 4.3, 4.6
Residential	MWh/a	9,809	1	
Public services & spaces	MWh/a	2,100	1	
Agriculture	MWh/a	300	1	
Transport	MWh/a	6,200	1	
Industry & businesses	MWh/a	7,700	1	
No. of ICEs per capita	#	**0.67**	1	4.6
No. of EVs per capita	#	**0.001**	1	4.6
Cumulative ESS capacity	%	**1**	1	4.3, 4.5
Electricity import	%	**95**	1	4.2, 4.3, 4.5
RES electricity self-production	%	**5**	1	4.1, 4.2, 4.3, 4.5
Environmental KPIs				
Energy-related emissions	t_{CO2eq}/a	**681.76**	3	4.2, 4.3
Residential	t_{CO2eq}/a	208.61	3	
Public services & spaces	t_{CO2eq}/a	132.92	3	
Agriculture	t_{CO2eq}/a	9.81	3	
Transport	t_{CO2eq}/a	0.10	3	
Industry & businesses	t_{CO2eq}/a	330.32	3	
Land use for energy	m^2/MW	**0**	1	4.6
Noise level	-	**None (0)**	4	
Visual impact	-	**None (0)**	4	
Social KPIs				
Citizen engagement	%	**5.10**	4	4.1, 4.4
Employment rate	%	**76.30**	1	4.1
Regulatory REC barriers	-	**Partial**	4	4.6
Energy poverty	%	**19.15**	4	4.2, 4.5
Economic KPIs				
Share of annual investments towards RES	%	**N/A**	1	4.6 / No reliable value can be measured currently

[4] Data quality scores: *1 assumption or estimation, 2 literature, 3 model output, 4 official statistics or data from surveys or interviews to citizens and local authorities, 5 actual registers, including monitoring data or calculations based on monitored data*. Scoring system adapted from the system applied in the EU Building Database (https://ec.europa.eu/energy/eu-buildings-database_en).

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3.5. Summary of KPIs for the baseline scenario in all demo sites

Table 28 summarizes all the baseline KPI values for each demo site to provide the reader with a convenient way of comparing the demos in order to crate understanding of their characteristic differences. Moreover, the comparison helps to obtain context and depth in understanding the baseline situation. However, it is noteworthy to mention that not all of the KPIs are absolute values, but also include estimates and subjective experiences of the locals. Such KPIs include Noise Level, Visual Impact, Citizen Engagement, and Energy Poverty.

Table 28: Summary of the recorded KPIs for each demo in the baseline situation.

KPIs for the baseline scenario						
KPI	Symbol	Unit	Kökar	Berchidda	Ispaster	Ollersdorf
Technical KPIs						
Peak electricity demand	P	MWh/h	**1.10**	**1.33**	**0.719**	**2.55**
Energy consumption	E	MWh/a	**14,980**	**25,825.43**	**9,787.8**	**26,109**
Residential	E_{resid}	MWh/a	2,532	17,234.87	1,455	9,809
Public services & spaces	E_{public}	MWh/a	806	3,707.33	179	2,100
Agriculture	E_{agric}	MWh/a	N/A	0	47.8	300
Transport	E_{transp}	MWh/a	10,355	4,514.11	7,992	6,200
Industry & businesses	E_{indus}	MWh/a	693	369.12	114	7,700
No. of ICEs per capita	ICE	#	**2.94**	**0.32**	**0.37**	**0.67**
No. of EVs per capita	EV	#	**0.004**	**0**	**0**	**0.001**
Cumulative ESS capacity	ESS	%	**0**	**0**	**25**	**15.0**
Electricity import	I	%	**60**	**86**	**96**	**95**
RES electr. self-production	RE_{el}	%	**40**	**14**	**4**	**5**
Environmental KPIs						
Energy-related emissions	$CO2$	t_{CO2eq}/a	**3,030**	**1,496.30**	**2,942**	**681.76**
Residential	$CO2_{resid}$	t_{CO2eq}/a	144	668.24	348.36	208.61
Public services and spaces	$CO2_{public}$	t_{CO2eq}/a	108	653.55	54.95	132.92
Agriculture	$CO2_{agric}$	t_{CO2eq}/a	N/A	0	15.60	9.81
Transport	$CO2_{transp}$	t_{CO2eq}/a	2,693	91.27	2,486	0.10
Industry & businesses	$CO2_{indus}$	t_{CO2eq}/a	46	83.25	37.73	330.32
Land use for energy	A	m^2/MW	**22,620**	**0**	**10**	**0**
Noise level	N	-	**Low (1)**	**Low (1)**	**None (0)**	**None (0)**
Visual impact	V	-	**Low (1)**	**None (0)**	**None (0)**	**None (0)**
Social KPIs						
Citizen engagement	CE	%	**6.90**	**0.98**	**3.72**	**5.10**
Employment rate	ER	%	**96.26**	**83.53**	**78.20**	**76.30**
Regulatory REC barriers	REC	-	**Partial**	**None**	**Partial**	**Partial**
Energy poverty	EP	%	**25**	**14.81**	**15**	**19.15**
Economic KPIs						
Share of annual investments towards RES	AI	%	**0**	**0**	**8**	**N/A**

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4/ Conclusion

A dedicated methodology for the evaluation of the demonstration actions which have been projected within the scope of LocalRES project has been carefully elaborated. The main purpose of this methodology is quantifying the operation and associated impact of the demonstration actions, including the LocalRES software solutions. A set of KPIs which address technical, environmental, economic, and social aspects have been developed in collaboration with the task group and demo teams, in line with those described in Task 1.2 (deliverable D1.2). For each of the KPIs, an evaluation framework has been defined, including one or more formulas and instructions about the recommended data sources, as well as about sensitivity analyses when necessary. Also, a 5-option system to effectively assess the quality of the data sources has been defined.

This deliverable document also presents the first results from the baseline studies conducted for all four demo sites in Finland, Italy, Spain, and Austria. The aim is creating a clear image of the current development trends of the energy systems that are currently in place and of the local aspects in general to form the basis of an evaluation framework that will capture the aspired impact of the LocalRES project once it has been fully implemented and is in operation. For each of the demo sites, the selected KPIs have been obtained for the conditions of the baseline scenarios, in close collaboration with WP1. These values will be updated at the end of the project in deliverable D4.7 *Impact assessment of LocalRES demonstration actions.*

This project has received funding from the European Union's Horizon 2020 Programme under the Grant Agreement no.

5/ Bibliography

A. Giordano, E. G. (2019). Planning of Energy Production and Management of Energy Resources in Local Energy Communities: The Case of Berchidda Municipality (Italy). *SP 2019*, *20(1), 16.* Cagliari, Italy. doi:https://doi.org/10.3390/proceedings2019020016

ÅSUB. (2021). *Statistical Yearbook of Åland 2021.* Mariehamn: Ålands statistik- och utredningsbyrå. Retrieved May 2, 2022, from Statistics and Research Åland: https://www.asub.ax/sites/www.asub.ax/files/attachments/page/statistisk_arsbok_for_aland_2021_0.pdf

E.Ghiani, A. L. (2019). Planning of a Smart Local Energy Community: The Case of Berchidda Municipality (Italy). *Energies 2019*, 12(24), 4629;. doi:https://doi.org/10.3390/en12244629

Energie Kompass. (2019). *Unsetzungskonzept Thermenregion Stegersbach.*

European Commission. (2020, October 10). *Energy prices and costs in Europe (COM/2020/951 final).* Retrieved from EUR-Lex: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1602774170631&uri=CELEX:52020DC0951

European Commission. (n.d.). *5-star Data Quality System*. Retrieved August 23, 2022, from EU Buildings Database: https://ec.europa.eu/energy/eu-buildings-database_en

Eurostat. (2018, September 3). *Energy Glossary*. Retrieved from Eurostats - statistics explained: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Category:Energy_glossary

Eurostat. (2020, September 9). *Energy statistics - cooling and heating degree days*. Retrieved from Eurostat metadata: https://ec.europa.eu/eurostat/cache/metadata/en/nrg_chdd_esms.htm

FMI. (2022). *Heating degree days*. Retrieved from Finnish Meteorological Institute: https://en.ilmatieteenlaitos.fi/heating-degree-days

INE. (2022). *Demografía Ispaster*. Retrieved from Foro-ciudad: https://www.foro-ciudad.com/vizcaya/ispaster/habitantes.html#EvolucionGrafico

ISTAT. (2022). *Popolazione Berchidda 2001-2020*. Retrieved from Tutti Italia: https://www.tuttitalia.it/sardegna/29-berchidda/statistiche/popolazione-andamento-demografico/

Johannes Thema, F. V. (2020, May). *EPOV Indicator Dashboar - Methodology Guidebook.* Wuppertal: EU Energy Poverty Observatory.

Vainio, T., & Nordlund, E. (2020). *Kökar Clean Energy Transition Agenda.* Mariehamn: Coast4us. Retrieved from https://clean-energy-islands.ec.europa.eu/countries/finland/kokar

This project has received funding from the European Union's Horizon 2020 Programme under the Grant Agreement no.

Visit Åland. (2022). *Maps of Åland*. Retrieved from Visit Åland: https://visitaland.com/en/plan-your-journey/maps-of-aland/

WRI & WBCSD. (2021, March). *The GHG Emissions Calculation Tool*. Retrieved from Greenhouse Gas Protocol: https://ghgprotocol.org/ghg-emissions-calculation-tool

This project has received funding from the European Union's Horizon 2020 Programme under the Grant Agreement no.

ANNEX I – LocalRES Citizen Survey

LocalRES questionnaire form for the demo areas

This questionnaire gathers information from the demo sites regarding the project's key performance indicators. The questionnaire is to be answered before and after the implementation of the LocalRES demo actions. All the answers will be completely anonymous and treated according to the EU's General Data Protection Regulation (GDPR).

This project has received funding from the European Union's Horizon 2020 Programme under the Grant Agreement no. 957819.

* Required

1. In which LocalRES demo area do you live in? *

- ◯ Kökar, FI
- ◯ Ispaster, ES
- ◯ Berchidda, IT
- ◯ Ollersdorf, AT
- ◯ None of the above

2. How many persons live in your household? *

3. In your everyday life, are you exposed to any sounds from the local energy production? *

- ◯ Yes
- ◯ No
- ◯ Maybe

4. If yes/maybe, how much does it bother you? (Skip this, if you selected 'no' in the previous question)

- ◯ 1 - Not at all, I am adjusted to it
- ◯ 2 - A little, it disturbs me seldom
- ◯ 3 - Quite a bit, it disturbs me frequently
- ◯ 4 - A lot, it disturbs me most of the time
- ◯ 5 - Too much, the sound is unbearable

5. In your everyday life, do you perceive any visual harm from your local energy production units? *

- ◯ Yes
- ◯ No
- ◯ Maybe

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6. If yes/maybe, how much does it bother you? (Skip this, if you selected 'no' in the previous question)

- ◯ 1 - Not at all, I am adjusted to it
- ◯ 2 - A little, it disturbs me seldom
- ◯ 3 - Quite a bit, it disturbs me frequently
- ◯ 4 - A lot, it disturbs me most of the time
- ◯ 5 - Too much, the sight is unbearable

7. Approximately, how large share of your household's annual net income is spent on power, gas, or heat? *

- ◯ Less than 5%
- ◯ More than 5, less than 10%
- ◯ More than 10, less than 15%
- ◯ More than 15, less than 20%
- ◯ More than 20, less than 25%
- ◯ More than 25, less than 30%
- ◯ More than 30, less than 45%
- ◯ More than 45, less than 50%
- ◯ More than 50%
- ◯ I don't know / I don't want to answer

This project has received funding from the European Union's Horizon 2020 Programme under the Grant Agreement no.

This project has received funding from the
European Union's Horizon 2020 Programme
under the Grant Agreement no. 957819