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SMILE

Smart Island Energy Systems

Deliverable D6.4

Cost-benefit analysis, Cost-effectiveness analysis and relevant social impact

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Executive Summary

The overall scope of SMILE project is to demonstrate, in real-life operational conditions, a set of both technological and non-technological solutions adapted to local circumstances targeting distribution grids to enable demand response schemes, smart grid functionalities, storage, and energy system integration with the final objective of paving the way for the introduction of the tested innovative solutions in the market in the near future. To this end, three large-scale demonstrators have been implemented in three island locations in different regions of Europe with similar topographic characteristics but different policies, regulations, and energy markets: Orkneys (UK), Samsø (DK) and Madeira (PT).

This deliverable describes the outcomes of the cost-benefit analysis, cost-effectiveness analysis and social impact assessment carried out in the framework of the project. In particular, this report consists of seven chapters including the Executive Summary and the References sections. In the introductory chapter, a general overview of the deliverable is presented alongside the aim and main objectives, as well as its relation to other tasks and deliverables of the SMILE project. Chapter 2 presents an overview regarding smart grid projects in Europe, and the implementation of Cost Benefit Analysis methodology as a mean to assess the efficiency and sustainability of said projects. In Chapter 3, there is the presentation of the CBA methodology that is proposed to be implemented for the SMILE demonstrator sites, while in Chapter 4 the results of the implementation of the methodology are presented for each demo site, followed by a sensitivity analysis in various parameters. The CBA analysis is complemented by a social impact assessment, based on the principles of social life cycle assessment (Social LCA). The Social CBA methodology and the results from its implementation are presented in Chapter 5, alongside a sensitivity analysis on the different stakeholder categories. Finally, Chapter 6 includes the conclusions of this deliverable.

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1 Introduction

1.1 Scope and Objectives

The overall scope of SMILE project is to demonstrate, in real-life operational conditions, a set of both technological and non-technological solutions adapted to local circumstances targeting distribution grids to enable demand response schemes, smart grid functionalities, storage, and energy system integration with the final objective of paving the way for the introduction of the tested innovative solutions in the market in the near future. To this end, three large-scale demonstrators have been implemented in three island locations in different regions of Europe with similar topographic characteristics but different policies, regulations, and energy markets: Orkneys (UK), Samsø (DK) and Madeira (PT).

Aim of this deliverable is to perform a comprehensive Cost Benefit Analysis (CBA) for the implemented solutions of the SMILE project regarding the operation of smart grids, especially islandic ones. Alongside the CBA, a social impact assessment will be performed, analyzing the social performance of each demonstrator through specific stakeholder categories. The demonstrator sites of SMILE project include a wide variety of proposed actions for implementation, ranging from Battery Energy Storage System (BESS), including electric vehicles and boats, to thermal energy storage systems. This aims to facilitate existing grids to become more sustainable in terms of efficiency, especially when compared with their current status of operation. Towards this aim, a wide range of solutions are proposed in order to make smart grids fed primarily by clean energy more promising for investors, more efficiently sustainable for TSOs and DSOs, and more practical and cheap for consumers, who might as well be RES producers.

Cost Benefit Analysis (CBA) was selected as a tool, since it is a process that can quantify and analyze decisions, systems, projects, and determine a specific value for different variables. CBA is mostly use on the planning stage of a new project to evaluate all the potential costs and revenues that might be generated from the project, and compare them to expected benefits. Hence, CBA is regarded a thorough, decision-making support tool. Specifically regarding the SMILE demonstrator sites, different CAPEX and O&M costs were examined for each demo site, due to the different needs and installed equipment. Furthermore, in order to quantify the potential costs and benefits for each demonstrator of SMILE project, a set of questionnaires was developed and shared with the demo operators. The required data from these questionnaires were different for each demonstrator.

Finally, the CBA was complemented with a Social Cost Benefit Analysis for each demo site. The Social CBA was based on the Social Life Cycle Assessment (S-LCA) methodological approach. S-LCA is a method that can be used to assess the social and sociological aspects of products, their actual and potential positive as well as negative impacts along the life cycle. This looks at the extraction and processing of raw materials, manufacturing, distribution, use, reuse, maintenance, recycling and final disposal. Aim of this social impact assessment is to evaluate potential social impacts of a throughout the life cycle stages of each demo site. The S-CBA for each demo site was based on an already established methodology, creating specific questionnaires tailored to the needs and existing situation of each demo site. Three stakeholder categories were identified and examined in respect to how they are affected by the implementation of the SMILE proposed solutions.

1.2 Structure of the deliverable

The document is structured on the following chapters:

- Chapter 2 includes a literature review of the existing situation of Smart Grid projects in EU, as well as relevant CBA case studies. The main focus of this chapter is to examine CBA of Smart Grid projects, especially the selected benefits that was examined in each case study.
- In chapter 3, there is a presentation of the methodological framework that was selected for this CBA study. Furthermore, there is a brief presentation of the SMILE demo projects, their boundaries, their specific needs and characteristics that eventually determined the selection of specific costs and benefits.
- Chapter 4 provides the application of the above mentioned methodological framework in the SMILE demonstrators and the presentation of the CBA results for each demonstrator. A baseline scenario was implemented for each demonstrator in order to facilitate the results of the CBA.
- Chapter 5, provides a dedicated literature review regarding Social Life Cycle Assessment (S-LCA). S-LCA was used as a methodology in order to perform the Social CBA, and quantify the relevant social impacts of the implementation of the SMILE project.
- Chapter 6 includes the main conclusions and suggestions both for the CBA and for the S-CBA implementation and results.

1.3 Relation to other Tasks and Deliverables

The present document provides a cost benefit analysis and social impact assessment for the Samsø, Orkneys, and Madeira demo sites under the SMILE project framework. This deliverable is directly related to several other tasks and deliverable of SMILE project.

- D6.1 “Report on selected evaluation indicators”[1] provides a significant amount of data regarding the demo sites under examination. Furthermore, KPIs addressed in D6.1 provide a basis for the relevant cost-benefit and social assessment.
- D6.2 “Methodological framework for conducting socioeconomic studies” (confidential) provides significant information regarding the overall goals of each demo site, as well as, identifying potential stakeholders that are also used in the context of this deliverable.
- D6.3 “Report on LCA/LCC tool and results”[1] provides a significant amount of data for the baseline scenario examined in the cost benefit analysis.

[1] https://cordis.europa.eu/project/id/731249/results

2 Smart Grid Projects in Europe

2.1 Existing Situation

The primary goal of modernizing power and energy infrastructures is to improve network stability, supply reliability, and provide energy to consumers at sustainable, fair, and affordable rates [1]. A smart electricity grid project can create new opportunities to safely integrate renewable energy sources to the existing grid, incorporate electric vehicles into the network, deliver electricity in a more sustainable, secure, and efficient way, as well as enable consumers to have greater control over their electricity consumption [2]. Several applications are enabled through smart grid projects such as: i) smart distribution management, ii) smart metering, iii) smart energy storage, iv) integration of electric vehicles [3; 4; 5].

From this point of view, smart grid projects are a step towards the development of the future energy and electricity supply system. Smart grid projects are important for energy providers and distributors and the operation of the grid, but furthermore, it is important to establish a close relationship with the consumers and involve them as active participants. This close relationship between the providers and the consumers could fulfill the full potential of the new services of a smart grid [6].

The last official EU outlook regarding Smart Grid projects was published in 2017, hence data from 2015 and 2017 will be presented as follow. Over the past 10 years, smart grid projects within EU have drastically increased. In 2015, within EU, there were 459 smart grid projects with a total investment budget over 3 billion €. These projects can be categorized as R&D (Research and Development) and D&D (Demo and Deployment). R&D projects aim to increase the know-how of the implementation of such technologies, while D&D projects target the implementation in realistic scenarios in order to assess the performance of such technologies [7]. These projects can also be categorized as national and multinational (collaboration between countries). The number of national and multinational projects in R&D and D&D projects is presented in Table 2.1.

Table 2.1 European national and multinational smart grid projects by stage of development in 2015.

-	National	Multinational	Total
R&D	87	124	211
D&D	85	163	248
Total	172	287	459

In 2015, the country with the most national smart grid projects was Denmark, followed by United Kingdom, Austria, and France, while, regarding multinational projects, Germany was the leading country (105) followed by Spain (97), and Italy (89). The overall number of projects per year, from 2002 to 2015, is presented in Figure 2-1.

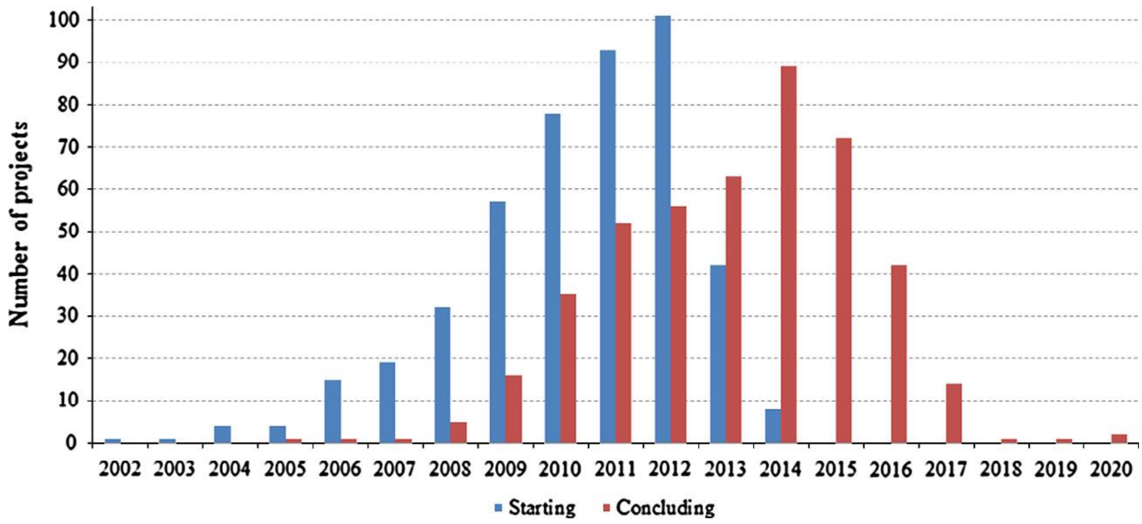


Figure 2-1 Smart grid projects in EU per year (Colak et al., 2015)

Specifically regarding cities with Smart Grid projects, Paris, London, and Rome are the ones that showcase the biggest investments in such projects, with a budget that overcomes €100 million collectively. These investments target the integration of RES in the existing network, smart network management, grid monitoring and remote grid control. Furthermore, there is focus on ensuring the sustainability and stability of the grid [2].

The emerging importance of Smart Grid projects can be highlighted by the fact that within two years (2015-2017) the projects grew from 459 to 950. The overall financial investment is totaling around €5 billion. The summary of the 2017 data are presented in Figure 2-2.

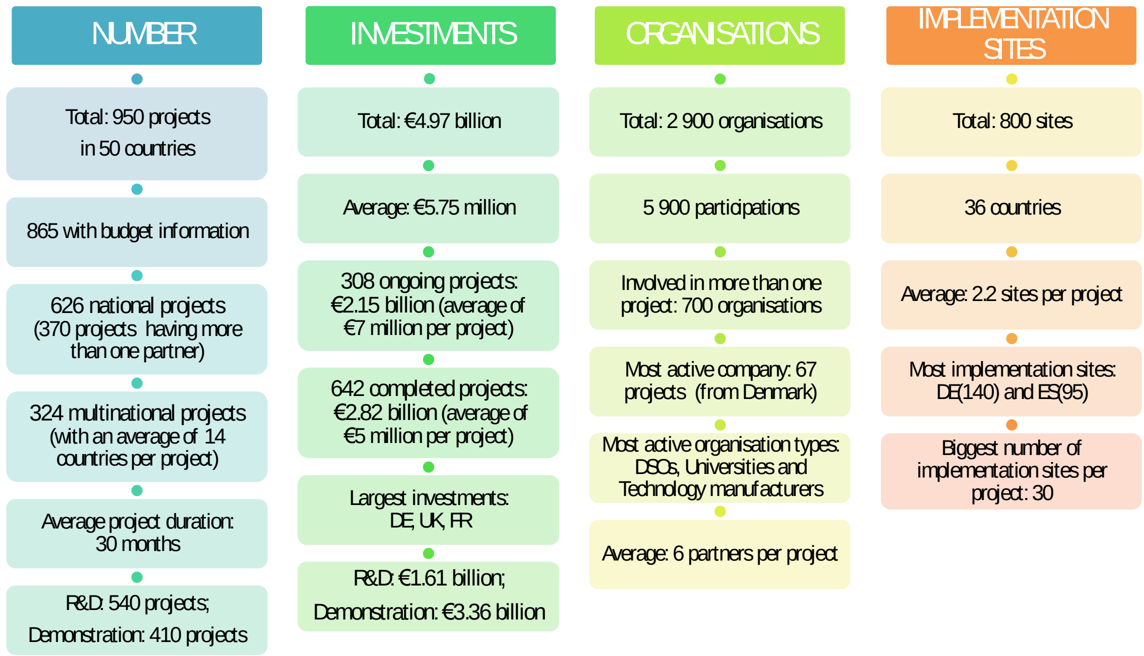


Figure 2-2 Summary of Smart Grid Project in EU, 2017 [6]

The budget allocation for R&D and D&D smart grid projects per country within the EU, is presented in Figure 2-3.

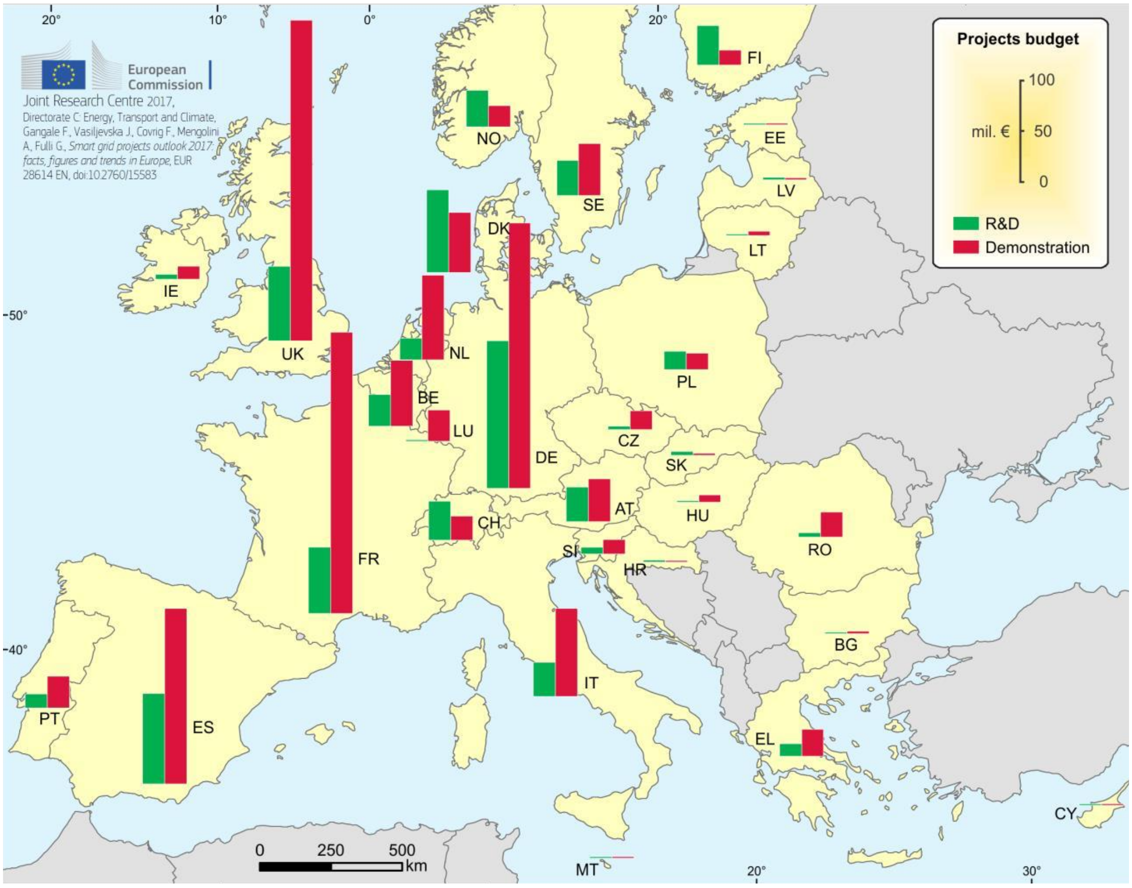


Figure 2-3 Smart Grid investments per country, within EU [6]

It becomes evident that countries invest more in demonstration projects in order to achieve immediate implementation of new technologies and capitalize on the benefits resulting from this implementation. The countries with the majority of smart grid projects remain Germany, France, and Spain, with most of the projects being D&D, as in most countries. An exception to this are the countries of Denmark, Norway and Poland where the investments are more

Regarding the technologies of smart grid projects, according to the JRC database, there are seven (7) main applications:

1. Smart network management
2. Integration of Distributed Energy Resources (DER)
3. Integration of large scale RES
4. Aggregation
5. Smart customer and smart homes
6. Electric Vehicles
7. Smart metering

The most adopted smart grid application currently in Europe is the smart network management, followed by smart customer and smart homes, and integration of DER and electric vehicles (Figure 2-4).

These applications seem to be the most implemented considering the local competence and the strategic national priorities for electricity distribution. As mentioned, the last official EU outlook regarding Smart Grid projects was published in 2017, hence it is assumed that number of project has been increased even more.

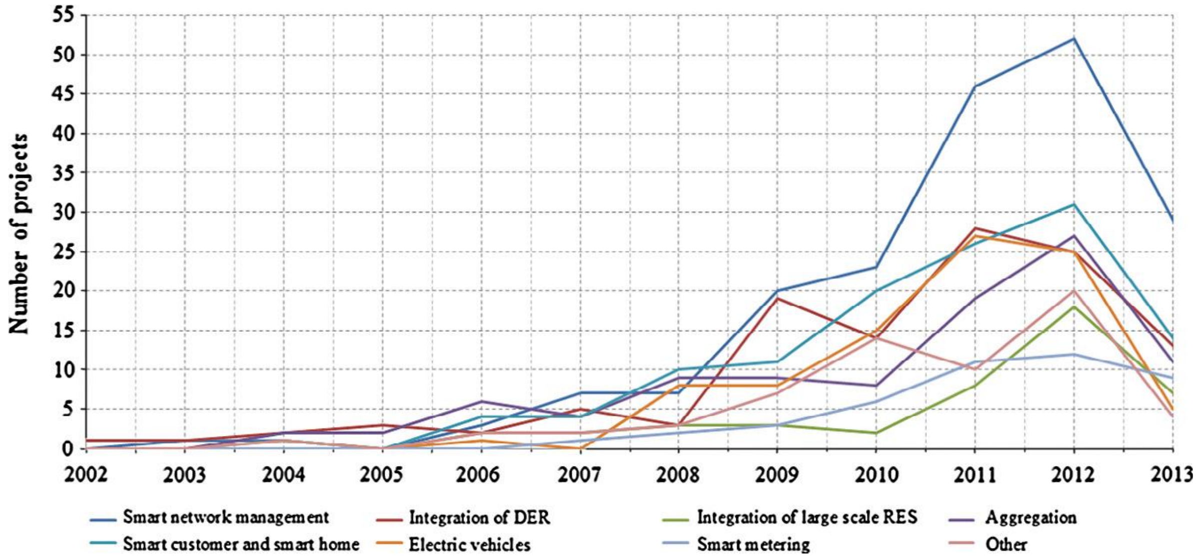


Figure 2-4 The distribution of smart grid applications [7]

2.2 CBA in Smart Grid Projects

A study in Europe in 2012, presented the results that only a small amount of smart grid projects had conducted a CBA regarding their activities. Some projects may have withheld data for confidentiality reasons. Others projects actually did not have a comprehensive CBA at all, because it was characterized being beyond the scope of the project. Their focus was mostly on assessing systems, implementations, and solutions from a technical point of view. Another explanation for the lack of established CBA may be that there is not a well-established CBA methodology for Smart Grid initiatives [8].

Since then, as of July 2018, every EU member state (except two) has conducted at least one CBA related to smart projects and smart meters, with mostly positive results [9]. Figure 2-5 provides a graphical overview of the most recent CBA results in EU, for the implementation of electricity smart meters. According the new European Electricity Directive, countries that present negative results to their CBA (such as Ireland and Germany) should regularly update their CBA, at least every 4 years or sooner, taking into account new technological changes and advancements, as well as market development.

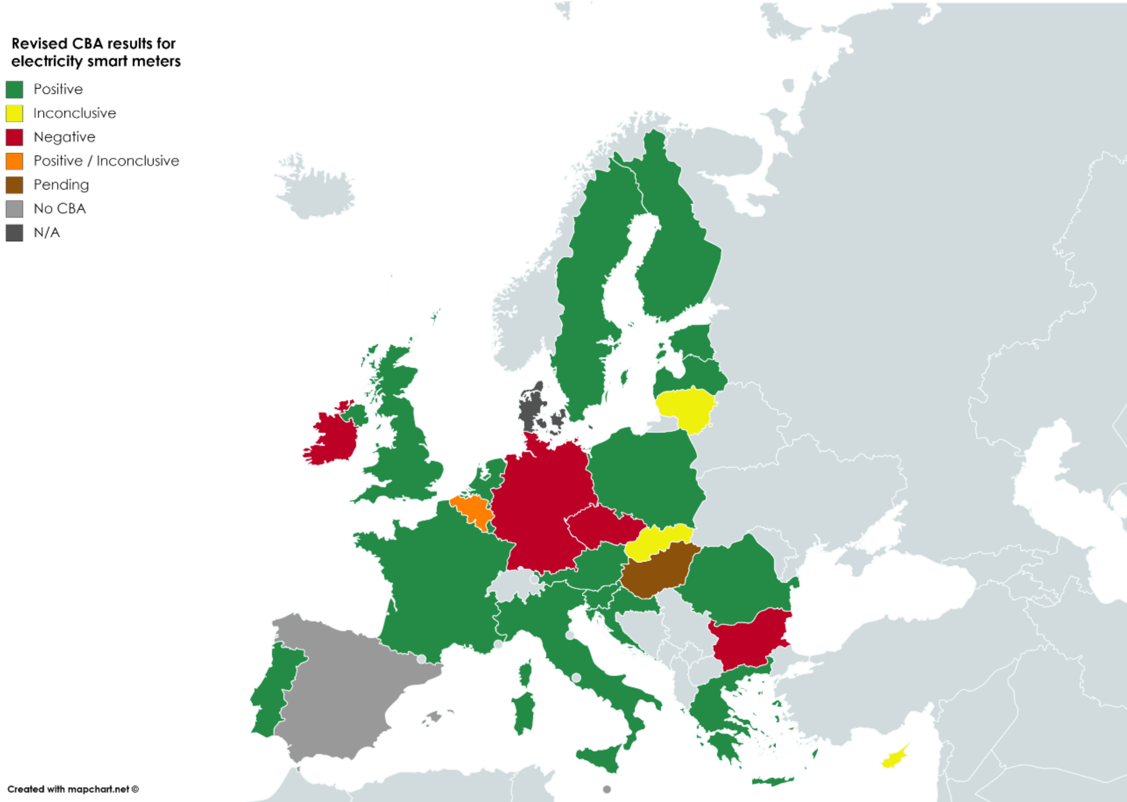


Figure 2-5 CBA results for electricity smart meters in the EU (as of July 2018) [9]

Figure 2-6 and Figure 2-7 present a list with the costs and benefits examined in all relevant CBA studies for each member state of the EU.

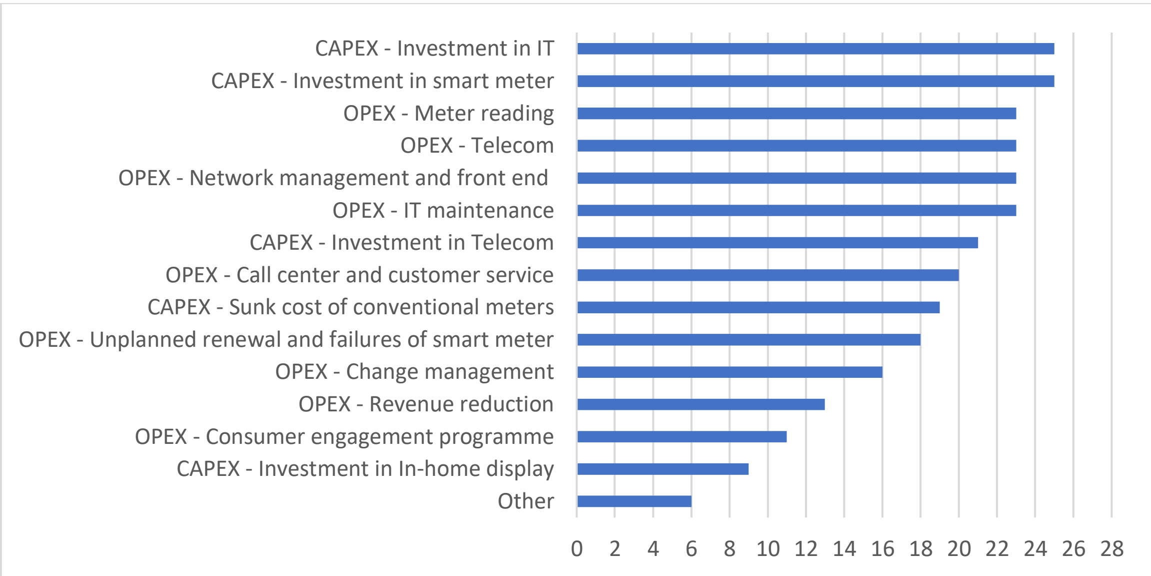


Figure 2-6 Ranking of considered CAPEX and OPEX costs (per number of Member States) [9]

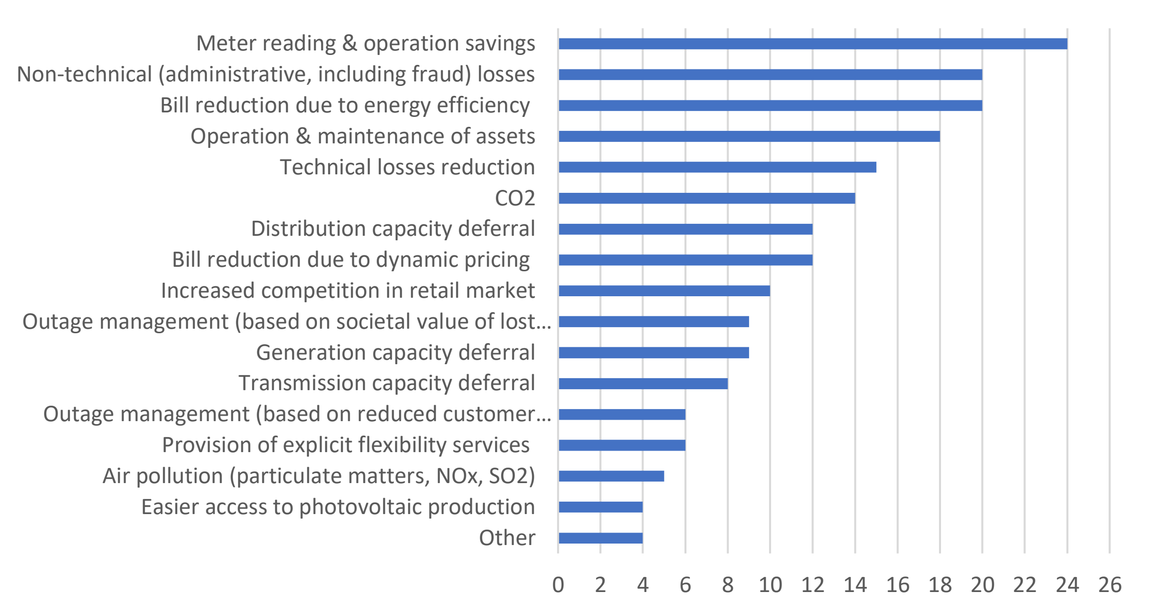


Figure 2-7 Ranking of considered benefits (per number of Member States) [9]

Regarding costs, most member states selected the capital investment in smart meters and IT support as the most common cost categories. These costs are followed by operational costs linked to maintenance, communications, and network management. Regarding benefits, most cases are focused from a consumer perspective. According to the CBAs from each member state, direct and indirect benefits for the consumers include [9]:

- Increased energy efficiency, as smart project allows consumers to monitor their energy consumption.
- Reduced consumer costs due to dynamic pricing.
- Operational savings and reduced other non-technical loses due to the smart meters and the automated readings.
- Potential reduction of services’ cost for the DSOs achieved by remote management of the system, may result to further economic benefits for the consumers.

3 Methodology

CBA could be characterized as a useful tool in order to assess smart grid projects and investments. In order to perform an analytical and in depth CBA, two scenarios need to be examined:

- Business as Usual: This is a baseline scenario developed for reference to facilitate the comparison with the planned projects [10]. This baseline scenario describes a prediction of what would be the case if the smart grid applications were not implemented. The baselines scenario could itself be a smart grid scenario, and be compared with a new scenario with further implemented actions. It is not necessary to represent a scenario with conventional grid technologies [11].

- New project implementation: This scenario included all the new elements and technologies that are, or going to be, implemented. If there are several planned projects, there should be a scenario for each project [10]. It is crucial to determine clear boundaries for this new scenario. The boundaries are determined by the lifetime of the project, and the geographic area of interest [11]. The lifetime of the project is the time horizon of the performed CBA. Typically, for energy projects, the lifetime may vary between 20 - 30 years [8].

The methodology selected for the CBA of the demonstrator sites of the SMILE project, was based on the guidelines/general approach proposed by the JRC Reference Report. The proposed methodology follows three main steps (Figure 3-1):

1. Definition of the boundaries. This step includes the definition of a baseline scenario and the proposed scenario, the selection lifetime of the project, as well as the selection of a discount rate.
2. Identification of costs and benefits both the baseline and the proposed scenario.
3. Sensitivity analysis of the CBA results with variations in different variables/parameters.

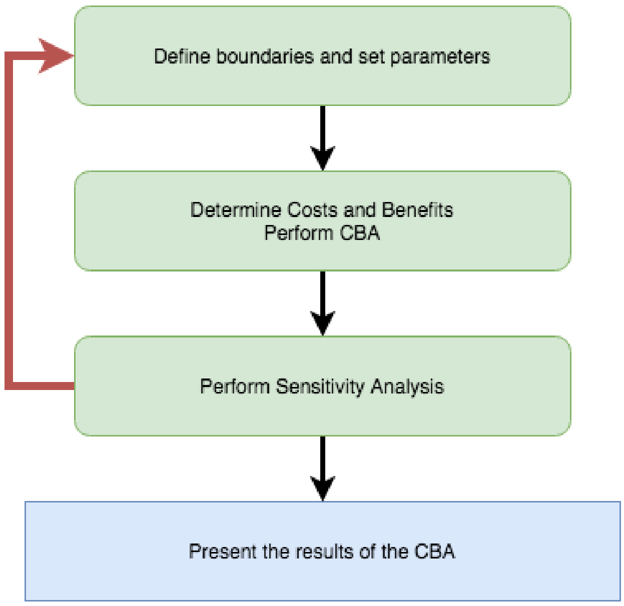


Figure 3-1 Steps for completing a CBA

3.1 Definition of the boundaries

The overall scope of SMILE project is to demonstrate, in real-life operational conditions, a set of both technological and non-technological solutions adapted to local circumstances targeting distribution grids to enable demand response schemes, smart grid functionalities, storage and energy system integration with the final objective of paving the way for the introduction of the tested innovative solutions in the market in the near future. To this end, three large-scale demonstrators have been implementated in three island locations in different regions of Europe with similar topographic characteristics but different policies, regulations and energy markets: Orkneys (UK), Samsø (DK) and Madeira (PT).

Since there are three different demonstrators, there is a need for developing three different baseline scenarios, as well as to examine three different smart grid scenarios. Hence, the CBA proposed methodology will be applied to each demonstrator, highlighting the characteristics and needs for each case. The baseline scenarios for each demonstrator are described in the following sections.

3.1.1 Samsø (DK) demonstrator - Baseline Scenario

In the Samsø demonstrator baseline scenario no smart grid solutions are implemented. This means that no PV and BESS are taken into account for the calculations. It is a business as usual scenario, with conventionally produced electricity and no storage solutions. The data for the baseline scenario that will be used for the CBA completion are presented in Table 3.1.

Table 3.1 Samsø Demonstrator - Baseline Scenario Data

Data	Value	Unit	Source
Electricity price	0.21	€/kWh	[18]; [19]; Provided by SMILE demo operator
Electricity losses	0	MWh (annually)	Provided by SMILE demo operator
Total electricity consumption by the customers	104	MWh/year	Provided by SMILE demo operator
Price for thermal energy	0.02	€/MJ	Provided by SMILE demo operator
Total thermal energy consumption by the customers	43,200	MJ (annually)	Provided by SMILE demo operator

3.1.2 Madeira (PT) demonstrator - Baseline Scenario

The baseline scenario of the Madeira demonstrator revolved around the existing situation. In Madeira, the whole energy is generated locally. Madeira electric energy system is based on conventional thermal power plants and hydro plants, complemented by a solid amount of wind energy and steady growing solar energy production. The baseline scenario does not take into account any storage solution. The data for the Madeira demonstrator baseline scenario are presented in Table 3.2.

Table 3.2. Madeira (PT) demonstrator - Baseline scenario data

Data	Value	Unit	Source
Electricity price	0.186 (daytime)	€/kWh	Provided by partner
	0.095 (nighttime)		
Electricity losses	0	MWh (annually)	Provided by partner
Total electricity consumption by the customers	31,76 (daytime)	MWh (annually)	Provided by partner
	13,61 (nighttime)		
Price for thermal energy (oil)	0.02	€/MJ	[20]; Assumption
Total thermal energy consumption by the customers	84,430	MJ (annually/per household)	[21]; assumption

Regarding the data, a combination of available statistics and assumption was utilized. Electricity and thermal energy price were obtained through the relevant partner and [20], while the total electricity and thermal energy consumption were obtained through the relevant partner, and the Portuguese statistic agency. Assumptions are considered as well regarding the energy mix used for the thermal energy consumption. The uncertainty of the results is mitigated by the implementation of sensitivity analysis carried out within this study.

3.1.3 Orkneys (UK) demonstrator - Baseline Scenario

The Orkneys demonstrator baseline scenario consists of a heating system utilizing a conventional oil boiler. The oil boiler has an estimated operation time of 4 hours on a daily basis. The data for the Orkneys baseline scenario are presented in Table 3.3.

Table 3.3. Orkneys demonstrator site - Baseline scenario data

Data	Value	Unit	Source
Electricity price	12.40	€/kWh (if on a 24-hour flat rate)	Provided by SMILE demo operator
Electricity losses	0	MWh (annually)	Assumption
Total electricity consumption by the customers	3.3	MWh (annually per household)	[22]
Price for thermal energy (oil)	0.05	€/MJ	Provided by SMILE demo operator
Total thermal energy consumption by the customers	93,600	MJ (annually)	Provided by SMILE demo operator

The data for the Orkneys demonstrator baseline scenario were provided by the relevant partner. The yearly electricity consumption per household was obtained from Switch-Plan, specifically regarding Orkney county.

The SMILE smart grid scenarios to be compared to the established baseline scenarios are presented as follows.

3.1.4 Samsø (DK) demonstrator - SMILE Scenario

This pilot refers to the implementation of an integrated energy system at the Ballen marina and its surroundings, comprising the renewable generation (PV panels) linked to a central storage unit (BESS). The BESS was installed in the Ballen Marina in order to store excess power from the PV plant during daytime, and deliver power during the evening and nights where most boats are docked in the marina and energy consumption is high. The nominal capacity of battery is 237 kWh corresponding to a 60kW$_p$ Photovoltaic system. The BESS can be charged from both the PV and the grid.

The PV system is expected to cover the electric consumptions of the following

- Boats
- Electric vehicles and
- Three buildings (located in Marina)
- Lighting and auxiliary equipment (pumps, tools)

The system boundaries of the Samsø demonstrator are presented in Figure 3-2.

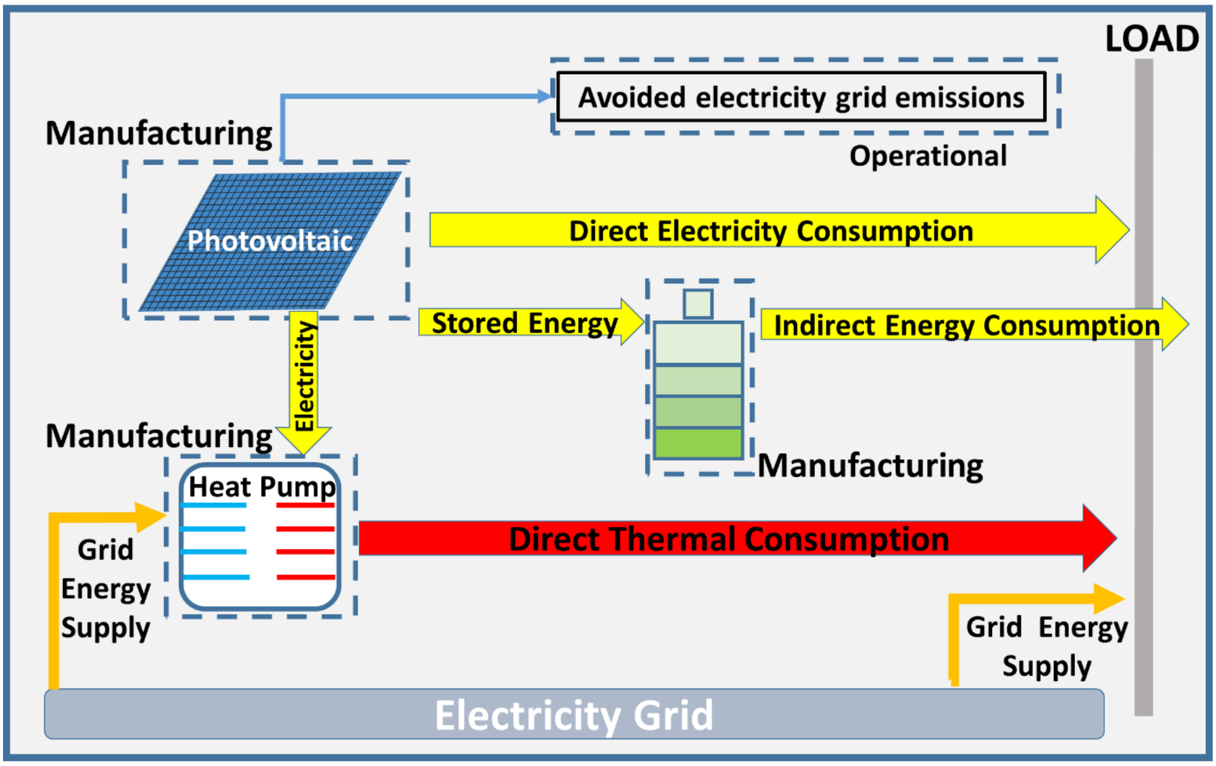


Figure 3-2 System boundaries of the installed technology for the 1st Pilot. Manufacturing phase of PV, BESS and Heat Pump will be taken into consideration

The required data for the Samsø SMILE scenario are presented in Table 3.4.

Table 3.4. Samsø demonstrator - SMILE scenario data

Data	Value	Unit	Source
Electricity losses	5.2	MWh (annually)	Provided by SMILE demo operator
Variation in electricity consumption with the smart grid implementation	0	%	Provided by SMILE demo operator
Heating needs covered by the heat pumps	43,200	MJ	Provided by SMILE demo operator
Value of Lost Load - Lower than Marginal Electricity Price	6,720	€/year	Provided by SMILE demo operator
Decrease in outage time	4%	%	Provided by SMILE demo operator

According to the provided data, after the implementation of the SMILE solutions, there is a 5% increase of grid electricity loses, however there is a 4% reduction in outage time of the network, which means that the consumers have less power outages, hence improved reliability of the overall network performance. Furthermore, there is no variation in the total amount of the electricity consumption, but the dependence on the grid is significantly changed. This means that the electricity consumption remains the same as in the baseline scenario, however the produced electricity relies on the SMILE implemented solutions. Hence the variation of electricity consumption is taken into account as 0% (Table 3.4). Finally, the installed heat pumps can cover 100% of the total thermal need of the baseline scenario.

3.1.5 Madeira (PT) demonstrator - SMILE Scenario

Madeira electric energy system is based on conventional thermal power plants and hydro plants, complemented by a solid amount of wind energy and steady growing solar energy production.

1st Pilot: Getting started with BESS and DSM (domestic scale)
The pilot refers to domestic UPACs equipped each with a PV module. The SMILE approach is about the installation of an 8 kWh BESS in each UPAC in order to maximize the self-consumption. This need was born by the barrier that UPACs have to sell the excess energy production from the PV to the utility really cheaply.

2nd Pilot: Moving forward with BESS and DSM (commercial scale)
The pilot refers to commercial UPAC, which is expected on a daily basis to consume all its PV production. There, a BESS can be pre-charged during off-peak periods to cover early morning loads, and then re-charged by the PV power to compensate the evening loads. The current state of technology in this scenario consists of one PV panel installed in a commercial prosumer.

3d Pilot: Getting started with EVs and smart charging

The approach on EVs' pilot will take into consideration:

- Pricing: Controlling the state of the charge based on the price of the electricity. The charger will be turned OFF during peak prices and ON during off-peak prices.

- Renewable availability: The charging can also be controlled based on the energy mix. This can be done considering the availability of renewables in the grid, thus being more advantageous to the DSO. Alternatively, it can be implemented considering local renewable availability for micro-producers, which can reduce the impacts (financial and environmental) of charging the EV directly from the grid.

4th Pilot: Electric Vehicles are our future
The second EV and smart charging pilot is focused on providing a smart charging solution using standard chargers by taking control of the ON/OFF status of the charge. The overarching goal of this pilot is to retrofit existing installation with hardware/software which would allow controlled charging.

5th Pilot: Voltage and Load Levelling
This pilot is focused on a properly dimensioned BESS which will support grid operation from voltage fluctuations due to the intermittency of photovoltaic production and provide load levelling services. The BESS will be discharged when the grid analyzer detects Voltage and/ or Frequency issues.

The system boundaries of the Madeira demonstrator are presented in Figure 3-3.

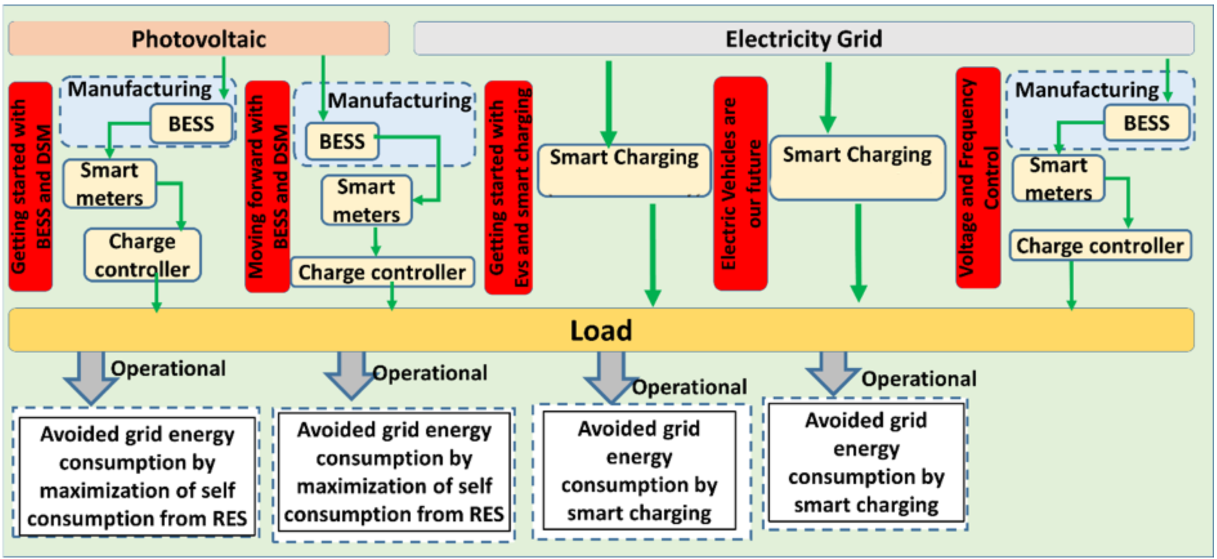


Figure 3-3 System boundaries of the installed technology for all the Pilots in Madeira. Manufacturing phase of PV and BESS will be taken into consideration

During the CBA study two sub-scenarios will be considered: i) the implementation of BESS and DSM, and ii) the implementation of EVs and smart charging. The required data for the Madeira SMILE scenario are presented in Table 3.5 and Table 3.6.

Table 3.5. Madeira demonstrator - SMILE scenario data (BESS and DSM scenario)

Data	Value	Unit	Source
Electricity losses	0	MWh (annually)	Provided by SMILE demo operator
Variation in electricity consumption with	-14	%	Provided by SMILE demo operator

the smart grid implementation			
Heating needs covered by the heat pumps	-	MJ	
Value of Lost Load - Lower than Marginal Electricity Price	5.12	€/kWh	[24]
Decrease in outage time	4%	%	Assumption

Table 3.6. Madeira demonstrator SMILE scenario data (EVs and smart charging)

Data	Value	Unit	Source
Electricity losses	0	MWh (annually)	Provided by SMILE demo operator
Variation in electricity consumption with the smart grid implementation	0	%	Assumption (intervention halted due to COVID-19 pandemic)
Heating needs covered by the heat pumps	-	MJ	
Value of Lost Load - Lower than Marginal Electricity Price	5.12	€/kWh	[24]
Decrease in outage time	4%	%	Assumption

Most of the required data for the Madeira SMILE scenario are based on data provided from the relevant partner. An assumption was taken into consideration regarding the decrease in outage time. Further sub-scenarios to observe fluctuations on the CBA will be presented in the Sensitivity Analysis chapter.

3.1.6 Orkneys (UK) demonstrator - SMILE Scenario

In the 1st pilot, domestic heat storage is implemented in order to exploit RES grid energy that would otherwise be curtailed. The domestic heat installations consist of approximately 45 properties, with a variety of different type of technologies implemented, including: 1) heat pumps, 2) Sunamp Phase Change Material (PCM) heat battery thermal store, 3) hot water tanks, and 4) batteries combined with VCharge/OVO dynamos. The different installations consist of:

- Type 1: 15 x 5.6 kW internally heated Sunamp PCM heat battery thermal store, VCharge/OVO controls
- Type 2: 15 x 5 kW air to water heat pump (ASHP), Sunamp PCM heat battery thermal store, VCharge/OVO controls
- Type 3: 10 x 5 kW ASHP, hot water thermal store, VCharge/OVO controls
- Type 4: 5 x 5 kW ASHP, hot water thermal store, BESS, VCharge/OVO controls

The system boundaries of the Orkney demonstrator are presented in Figure 3-4, Figure 3-5, Figure 3-6, and Figure 3-7, while the data regarding SMILE implemented solutions are presented in Table 3.7.

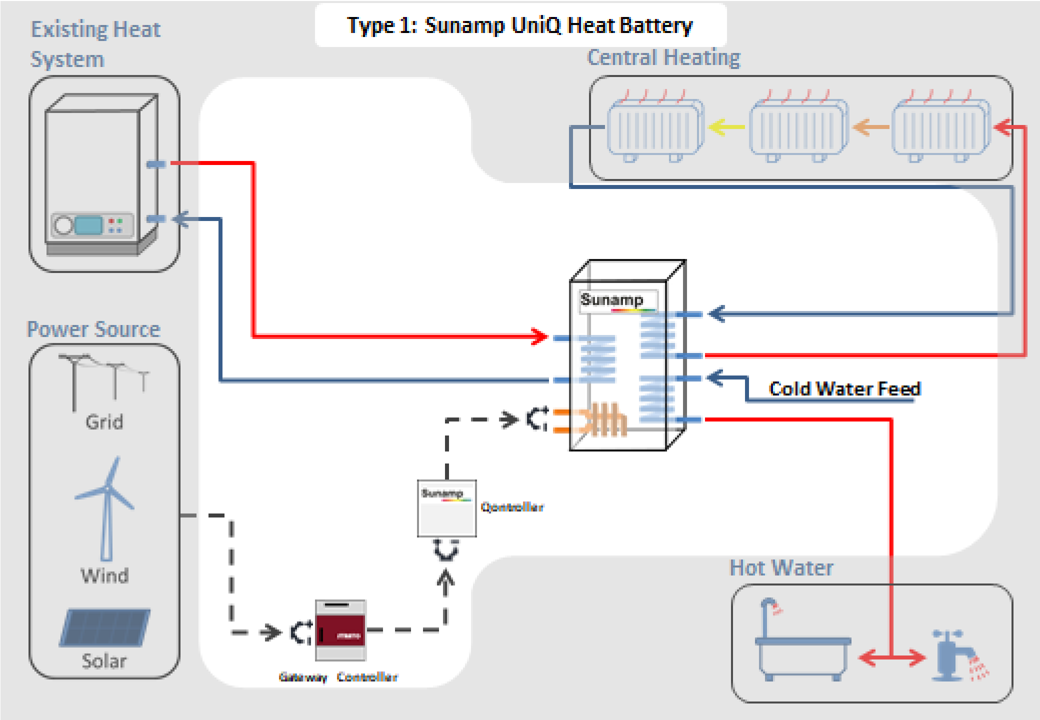


Figure 3-4 System Boundaries of the installed SMILE heating implementations in a typical example of a Type 1 domestic property, Orkney demonstrator

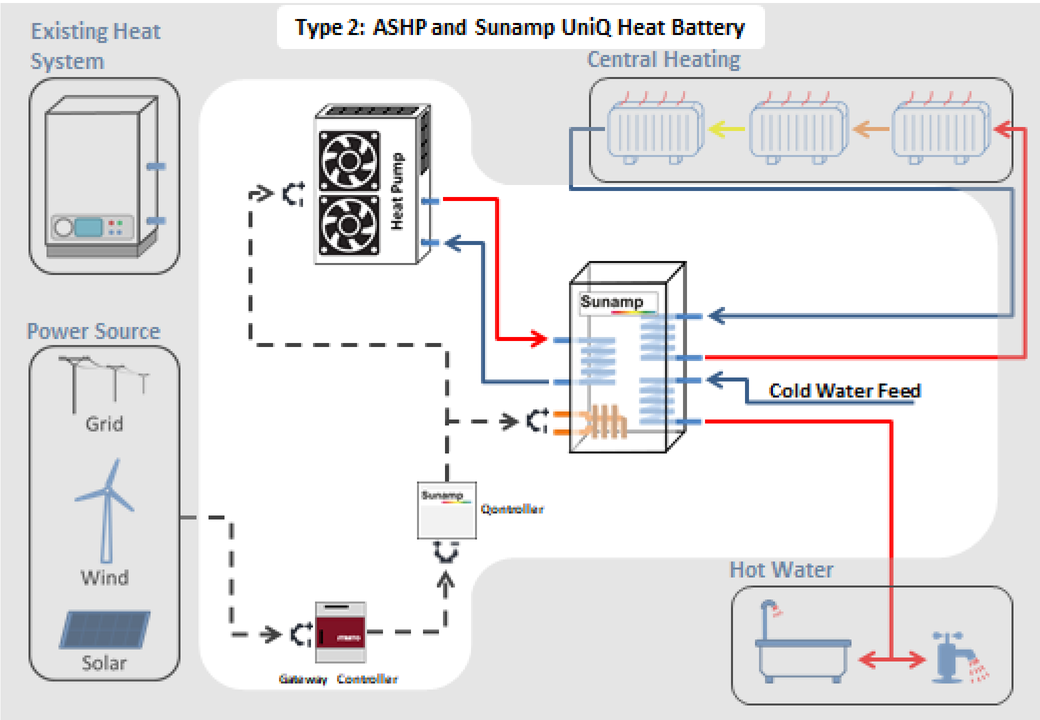


Figure 3-5 System Boundaries of the installed SMILE heating implementations in a typical example of a Type 2 domestic property, Orkney demonstrator

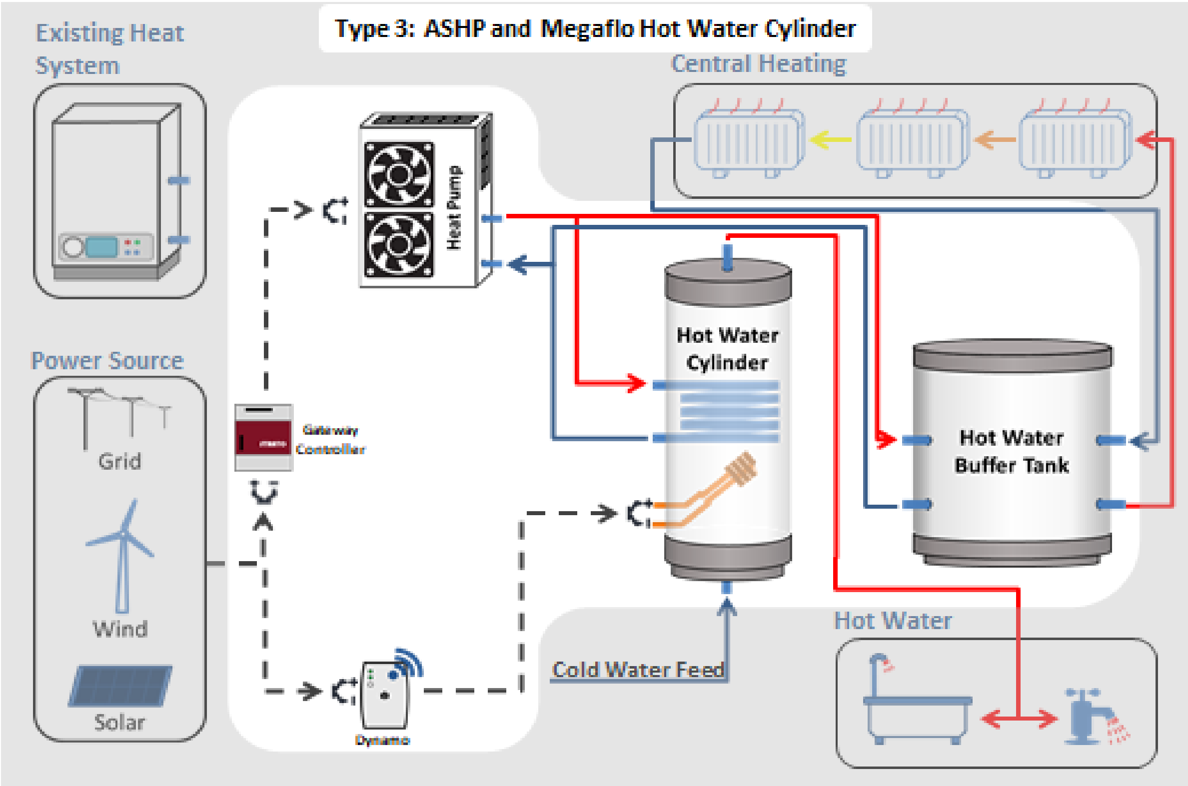


Figure 3-6 System Boundaries of the installed SMILE heating implementations in a typical example of a Type 3 domestic property, Orkney demonstrator

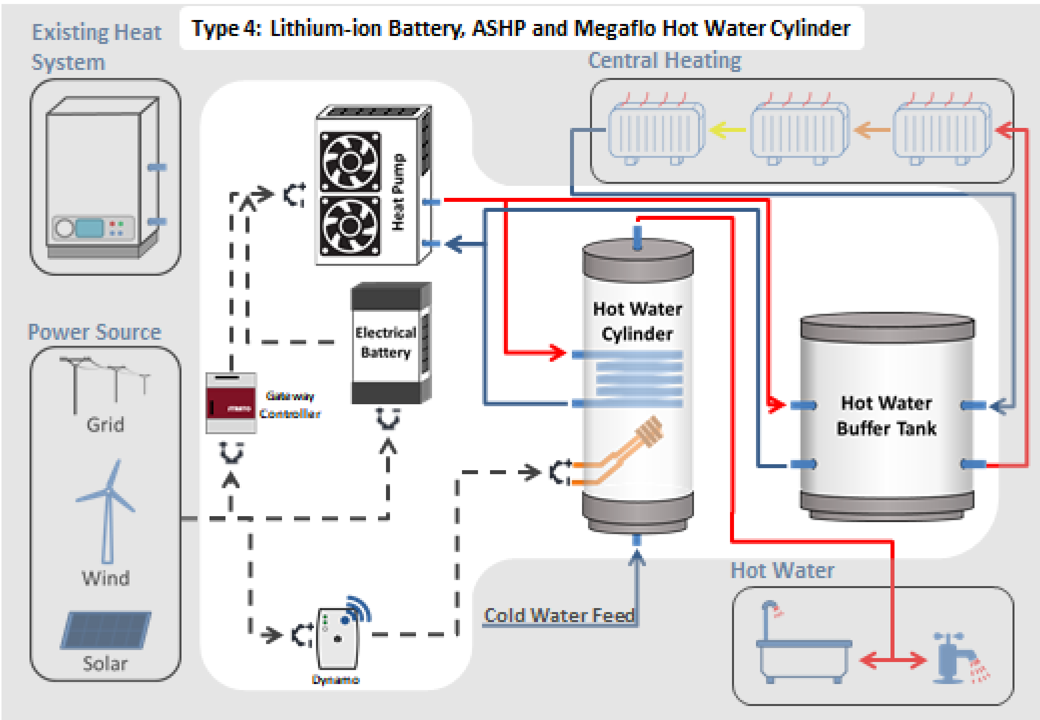


Figure 3-7 System Boundaries of the installed SMILE heating implementations in a typical example of a Type 4 domestic property, Orkney demonstrator

Table 3.7. Orkneys demonstrator - SMILE scenario data

Data	Value	Unit	Source
Electricity losses	0	MWh (annually)	Assumption
Variation in electricity consumption with the smart grid implementation	0	%	Provided by SMILE demo operator
Heating needs covered by the heat pumps	93,600	MJ	Provided by SMILE demo operator
Value of Lost Load - Lower than Marginal Electricity Price	19.24	€/kWh	[23]
Decrease in outage time	-5%	%	Provided by SMILE demo operator

Regarding the data for the Orkneys SMILE scenario, the relevant partner mentioned that there is not a noticeable variation in electricity consumption. The installed heat pumps operate at their maximum potential covering 100% of the heating needs of the area. However, SMILE installations appear to be less reliable regarding outage times, since they have led to 5% increase of the total outage time compared to the baseline scenario. This was due to the level of complexity introduced by some types of the installed equipment, and this number did not affect all properties of the demonstrator.

Regarding the lifetime of each demonstrator, the JRC proposed lifetime was implemented as 30 years. Finally, regarding the discount rate, in general at a European Level, societal discount rates range between 3.5% - 5.5% [8]. Furthermore, the World Bank has suggested a discount rate of 5% for similar projects [13]. Hence, the discount rate for the performed CBA will be selected as 5%, however various values will be examined during the sensitivity analysis.

3.2 Costs and benefits

The estimation of costs is a straightforward process. Most of the times, costs include up-front investment costs (Capital Expenditures - CAPEX), as well as operations and maintenance (O&M) costs. O&M costs may vary based on the project. In the case of SMILE case study, all three demonstrators present different CAPEX and O&M costs. Furthermore, regarding O&M costs, the CBA will be based on assumptions, since the demonstrators may not have encountered every possible cost.

As far as benefits, the situation becomes a little more complicated. The benefit is defined as a positive impact that adds value to a specific stakeholder [12]. The European Regulators Group for Electricity and Gas [14] recommended that when conducting a CBA for smart grid projects, it is important to recognize value not only for the Distribution System Operators (DSOs), but also for several actors affected by the projects, such as the customers themselves, and the community as a whole. Even though it is not required for a CBA to take a societal perspective, this CBA will take into account benefits for various stakeholders, in attempt to add further value to the project [11]. Potential benefits from a CBA can be classified as follows [10]:

- Economic benefits, e.g. optimized generator operation, deferred generation capacity investments, reduced ancillary service cost, reduced congestion cost, deferred transmission capacity investment, deferred distribution capacity investment, reduced equipment failures, reduced distribution equipment maintenance cost, reduced distribution operation cost, reduced meter reading cost, reduced electricity losses, detection of anomalies related to contracted power, reduced electricity cost;

- Benefits of reliability, e.g., reduced sustained outages, reduced major outages, reduced restoration cost, reduced momentary outages, reduced sags and swells;
- Environmental benefits, reduced CO_2 emissions, reduced SO_x, NO_x, and PM10 emissions, reduced/ augmented landscape use;
- Energy security benefits, e.g., reduced value of loss load (VOLL) and reduced wide-scale blackouts.

In order to quantify the potential costs and benefits for each demonstrator of SMILE project, a set of questionnaires was developed and shared among the demo operators. The required data from these questionnaires were different for each demonstrator. Regarding the calculation of the overall costs, the following cost categories were required:

- Equipment and installation costs in pilots
- O&M Costs
- Miscellaneous (electricity costs, external costs, etc.)

The required data for the calculation of the benefits are presented in **Error! Reference source not found.**

Table 3.8 Required Data for the calculation of benefits

Data	Unit	Short Description
Cost of equipment breakdowns for the baseline use case	€	Rough estimation for a lifetime of 20-30 years (tbd)
Cost of equipment breakdowns for the Smile use case	€	Rough estimation for a lifetime of 20-30 years (tbd)
Electricity losses for the baseline use case	MWh	Annual electricity losses - Estimation
Electricity losses for the Smile use case	MWh	Annual electricity losses - Estimation
Energy price during different times of day	€/MWh €/MWh €/MWh	e.g. electricity price during morning consumption, during nighttime etc.
Total electrical energy consumption by customers during daytime and nighttime	MWh MWh	Annual or daily electricity consumption by the consumers/customers for the baseline use case.
Variation in electricity consumption with the smart grid implementation during day and night time	MWh MWh	Annual or Daily electricity consumption for the Smile use case.
Price for thermal energy	€/MJ	
Total thermal energy consumption	MJ	Annual thermal energy consumption for heating needs by the customers, for the baseline use case.
Heating needs covered by the heat pumps	MJ	Annual thermal energy provided by the heating pumps in the Smile use case.

Value of Lost Load - Lower than Marginal Electricity Price	€/kWh	The value of lost load is typically set as a reference by national regulators, represents an estimated cost to the economy per kWh of electricity not supplied.
Decrease in outage time (%)	%	Rough estimation

The required data for the potential calculation of benefits were based on the methodology described by JRC and IRINA [8; 11]. The data collected for each demonstrator facilitate the calculation of selected benefits. The calculation of the selected benefits is presented in Table 3.9.

Table 3.9 Selected benefits for examination per stakeholder

Benefit	**Value**	**Main Stakeholder**
Reduced maintenance costs of assets	Value (€) = [Direct costs relating to maintenance of assets $(€)]_{Baseline}$ – [Direct costs relating to maintenance of assets $(€)]_{Smile}$	DSOs Municipalities
Reduced equipment failures	Value (€) = [Cost of equipment breakdowns $(€)]_{Baseline}$ – [Cost of equipment breakdowns $(€)]_{Smile}$	Technology Provider
Reduced electricity losses	Value (€) = (Electricity Loses Baseline use case - Electricity Loses Smile use case)* Energy Price	DSOs Municipalities
Reduced electricity cost	Value (€) = [Energy price (€/MWh) * Total energy consumption by customers (MWh)] - [Energy price * Energy Variation in Smile use case]	Customer
Reduced heating cost	Value (€) = [Heating needs covered by the heat pumps (MJ)] * [Price for thermal energy (€/MJ)]	
Reduced sustained outages	Value (€) = Average number of sustained interruptions per consumer during the year*Average duration of interruptions*Value of Lost Load*Electricity Consumption*Decrease in outage time	Customer
Reduced CO2 emissions	Each MWh saved is assumed to save 0.68 tons of CO2 (0.034 in the case Samsø because of higher wind energy share). Assuming a social cost of carbon of USD 40/ton CO2 (32.95 €) we can calculate the benefit of reduced CO2. (inflation should be taken into account).	Community

The aforementioned selected benefits can impact more than one main stakeholder category. Examples on how different stakeholder categories benefit from each benefit category are presented in Figure 3-8 and Figure 3-9 (for the cases of Reduced CO2 emissions and Reduced Equipment failures).

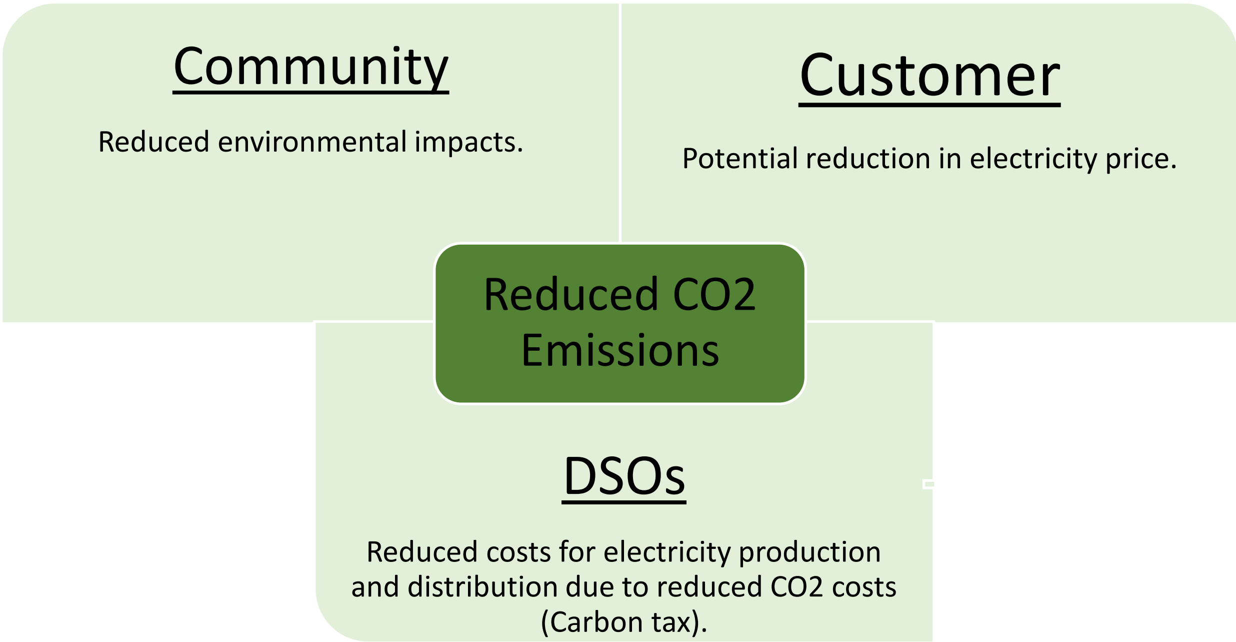


Figure 3-8 Reduced CO2 Emission benefit for various stakeholders

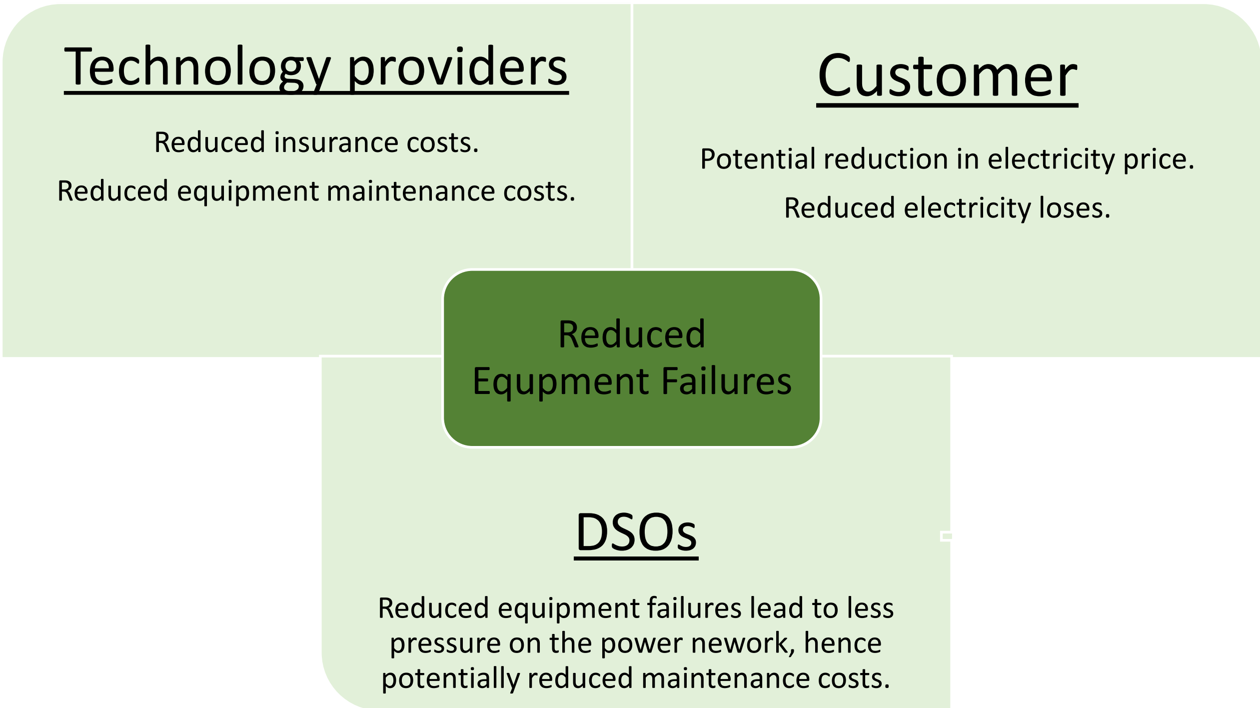


Figure 3-9 Reduced equipment failures benefits for various stakeholders

Further examination of the benefit categories regarding each stakeholder will be presented in the following Chapter regarding the results of the CBA.

4 Results of the CBA

The overall lifetime for the performed CBA was selected as 15 years, which was the minimum lifetime of specific installed equipment. The discount rate was selected at 5% based on [156]. Regarding the costs for the baseline scenarios the following assumptions were taken into consideration:

- The equipment and installation costs were not taken into account.
- According to [25], a smart grid may present 13-77% less O&M costs that a traditional grid. Hence, in this CBA, O&M and miscellaneous costs the baselines scenarios of all three demonstrator sites, are taken into account as 50% higher compared to the smart grid SMILE scenarios. This parameters will be taken into consideration within the sensitivity analysis

The following two (2) KPIs are calculated:

- Net Present Value (NPV)
- Benefit-Cost Ratio (BCR)

For the calculation of Net Present Value (NPV) the following formula is applied:

$$NPV = \sum Present\ Value\ of\ Future\ Benefits - \sum Present\ Value\ of\ Future\ Costs$$

For the calculation of the present values of costs and benefits, the present value factor is needed. The present value factor is equal to 1/(1+r)^n, where r is the discount rate, and n the lifetime of the project. In the case of SMILE, where the discount rate is 5%, and the project's lifetime is 15 years the present value factor is equal to 0.48. The formula for calculating the present value is:

- Present Value of Future Benefits = Future Benefits*Present Value Factor
- Present Value of Future Costs = Future Costs*Present Value Factor

The formula for the calculation of the Benefit-Cost Ratio is:

$$BCR = \sum Present\ Value\ of\ Future\ Benefit \,/ \sum Present\ Value\ of\ Future\ Costs$$

4.1 Samsø Demonstrator Results

The cost allocation for the Samsø demo site (and the other demo sites) regarding Equipment and installation costs and O&M costs is provided by the relevant partner, with one assumption for the miscellaneous costs based on Deliverable 6.3 "Report on LCA/LCC tool and results". The various costs for the Samsø demo site are presented in Table 4.1.

Table 4.1 Cost allocation for the SMILE Samsø demo site

Cost	Value (€)
Equipment and Installation costs in Pilots	238,959
O&M costs - for 15 years	12,750

Miscellaneous (electricity costs, external costs etc.) - For 15 years	12,164
Total costs for 15 years	**263,873**

The equipment and installation costs include 60 kWp PV panel, as well as a 240 kWh BESS. The PV system has a lifetime of 25 years, so at the end of the projects lifetime which was set at 15 years, the PV system will still have residual value. The O&M costs take into account only expected maintenance costs, since it is difficult to foresee any unexpected damage which would require a higher amount of money to be repaired. Finally, regarding the miscellaneous costs, one major assumption that was taken into account is that the project will be dependent on the grid for the 1st year of operation, but after that it would become self-sufficient, lowering the cost for grid electricity, as well as external costs (CO2 taxes for example).

The calculation of benefits for the Samsø demonstrator are presented in Table 4.2. For the calculation of benefits, the data for the baseline and SMILE scenario in Table, and Table are utilized.

Table 4.2. Benefits from the SMILE implementation on the Samsø Demonstrator (15 years)

Benefit	Result	Unit
Reduced maintenance costs of assets	12,457	€
Reduced equipment failures	6,375	€
Reduced electricity losses	-12,480	€
Reduced electricity cost	188,528	€
Reduced heating cost	25,200	€
Reduced sustained outages	50,170	€
Reduced CO2 emissions	276	€
TOTAL BENEFITS	**266,625**	**€**

The selected benefit categories show that the SMILE implemented solutions are expected to be financially beneficial for the demonstrator site. Every benefit category selected for calculation present significant earnings compared to the baseline scenario. However, SMILE scenario presents more costs compared to the baseline scenario in the reduced electricity losses category. According to data provided by the relevant partner, SMILE installations cause an increase on electricity losses, leading to a 12,000 € loss over the lifetime period of the project.

The NPV of the Samsø Demonstrator for the SMILE scenario is as follows:

Present Value of Future Benefits = 271,861*0.48= 127,980

Present Value of Future Costs 263,873*0.48= 126,659

Hence,

$$\mathbf{NPV_{Samsø} = 1{,}321\ €}$$

The BCR of the Samsø Demonstrator for the SMILE scenario is calculated as follows:

$$\mathbf{BCR_{Samsø} = 1.01}$$

4.2 Madeira Demonstrator Results

The various costs for the Madeira demo site are presented in Table 4.3.

Table 4.3. Cost allocation for the Madeira demo site

Cost	Value (€)
Equipment and Installation costs in Pilots	96,264
O&M costs - for 15 years	52,500
Miscellaneous (electricity costs, external costs etc.) - For 15 years	5,369
Total costs for 15 years	**154,133**

The Equipment and Installation costs include every piece of equipment, without taking into account the PVs, which were already installed from the baseline scenario. The maintenance costs take into account the actual cost of the annual maintenance services, as well as some extra costs related to unexpected damages.

The calculations of the selected benefits for each scenario of the Madeira demonstrator are presented in Table 4.4.

Table 4.4. Benefits from the SMILE implementation on the Madeira Demonstrator (15 years)

Benefit	Result	Unit
Reduced maintenance costs of assets	28,934.50	€
Reduced equipment failures	26,250	€
Reduced electricity losses	0	€
Reduced electricity cost	118,392	€
Reduced heating cost	Not applied	
Reduced sustained outages	46,466	€
Reduced CO2 emissions	1,110	€
TOTAL BENEFITS	**221,152**	**€**

The NPV of the Madeira Demonstrator for the SMILE scenario is as follows:

Present Value of Future Benefits = 221,152*0.48= 106,153€

Present Value of Future Costs = 154,133*0.48= 73,983€

Hence,

$NPV_{Madeira}$ = 32,169.12 €

The BFR of the Madeira Demonstrator for the SMILE scenario is calculated as follows:

$BCR_{Madeira}$ = 1.43

4.3 Orkneys Demonstrator Results

The various costs for the Orkneys demo site are presented in Table 4.5.

Table 4.5. Cost allocation for the Orkneys demo site

Cost	Value (€)
Equipment and Installation costs in Pilots	1,168,573
O&M costs - for 15 years	1,601,280
Miscellaneous (electricity costs, external costs etc.) - For 15 years	2,811.50
Total costs for 15 years	**2,772,664**

The capital expenditures include mainly the purchase and installation of the following equipment:

- Boiler
- Heat pump
- Hot water cylinder
- How water buffer tank
- Heat Battery
- BESS

The boiler has a lifetime of 12 years; hence it needs to be replaced within the 15 years of the projects lifetime. The hot water cylinder and hot water buffer tank lifetime exceeds the lifetime of the project, subsequently they are considered to have a residual value. Regarding the O&M costs two main factors are taken into consideration, in order to compute the maintenance costs: 1) the actual expected costs provided by Orkneys pilot and 2) the estimation of unexpected costs, due to equipment parts failures (unlike the case of the Samsø demonstrator).

The calculated benefit results for the Orkneys demo site are presented in Table 4.6.

Table 4.6. Benefits from the SMILE implementation on the Orkneys Demonstrator (15 years)

Benefit	Result	Unit
Reduced maintenance costs of assets	802,046	€
Reduced equipment failures	800,640	€
Reduced electricity losses	0	€
Reduced electricity cost	400,950	€
Reduced heating cost	3,790,800	€
Reduced sustained outages	-2,571,426	€
Reduced CO2 emissions	9.680	€
TOTAL BENEFITS	**3,232,690**	**€**

The NPV of the Orkneys Demonstrator for the SMILE scenario is as follows:

Present Value of Future Benefits = 3,232,582*0.48= 1,551,691

Present Value of Future Costs = 2,772,664*0.48=1,330,879

Hence,

$$NPV_{Orkneys} = 220{,}812\ €$$

The BCR of the Orkneys Demonstrator for the SMILE scenario is calculated as follows:

$$BCR_{Orkneys} = 1.17$$

4.4 Discussion

The overall picture of the CBA results for each demo case is summarized in Table 4.7.

Table 4.7. Overall picture of CBA results (15-year lifetime)

	Samsø	Madeira	Orkney
Net Present Value (€)	1,321	32,168	220,812
Benefit-Cost Ratio	1.01	1,43	1,17

In the case of Samsø demonstrator, the Benefit-Cost Ratio of 1.01 shows that the benefits of the demo outweigh the costs for the lifetime of the project. Every selected benefit category shows profitable results, with the exception of reduced electricity losses. The biggest profit from the implementation of SMILE results from the reduction of electricity costs. The current installations lead to a reduction of 43% consumption from the grid, leading to a benefit of around 188,000€ over the lifetime of the project. Following, the reduced sustained outages lead to significant benefits. The implementation of SMILE solution leads to significant reduction on power outages, hence to a more sustainable network, which can be translated to a benefit of 50,170€, over the lifetime of the project. Furthermore, an important factor for the benefits resulting from SMILE installations is the decrease in outage times. Regarding the electricity losses category, according to the relevant partner, SMILE scenario leads to 5% increase of electricity losses compared to the business-as-usual/baseline scenario. This translates to a loss of around 12,000€ over the lifetime of the project.

Regarding Madeira demonstrator, the benefit-cost ratio of 1.43 shows that the demo is profitable on a 15-year lifetime, with the benefits far outweighing the costs. All the examined benefit categories appear to be profitable, with the exception of reduced electricity losses. Reduced electricity costs is the most profitable benefit category, leading to an overall benefit of 118,390 € during the projects lifetime. This is achieved through the shift of electricity consumption, from the traditional grid to the SMILE implemented solutions for electricity production. Furthermore, Madeira demonstrator profits from reduced sustained outages. Overall a benefit of 46,466 € over a period of 15 years is cumulated due to reduced outages and better performance of the electricity network. In the case of electricity losses, Madeira demonstrator has a neutral performance, neither benefiting, nor losing money. Moreover, Madeira demo case has not implemented solutions regarding heat consumption (heat pumps). A potential future implementation of heat pumps covering the needs of the area, may lead to significant financial benefits, a scenario that will be discussed in the sensitivity analysis section.

Finally, Orkneys demonstrator with a BCR of 1.17 appears to be profitable, as in the case of every demonstrator. The main profit derives from the benefit category of reduced heating cost, due to the implementation of heat pumps. This fact translates to a benefit of 3,790,800 € in a 15-year period of time. The benefit categories of reduced maintenance cost of assets and reduced equipment failures lead to a combined profit of around 1,600,000 €. However, despite having overall positive results, Orkneys demonstrator presents a loss of more than 2,500,000 € due to increased power outages. According to the relevant partner, SMILE installations appear to be less reliable than the business-as-usual/baseline scenario because of the level of complexity introduced by some install types, leading to a 5% increase of power outages. Based on the existing number of power outages and the average minute amount of each power outages in the UK [26], represented by the indexes SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index), this performance lead to losses amounting up to over 2,500,000 € over a 15-year lifetime. Subsequently, there is an important need to improve the overall demonstrator performance regarding power outages, in order to provide a more stable and sustainable network, and minimize potential financial losses, hence further improving the overall performance.

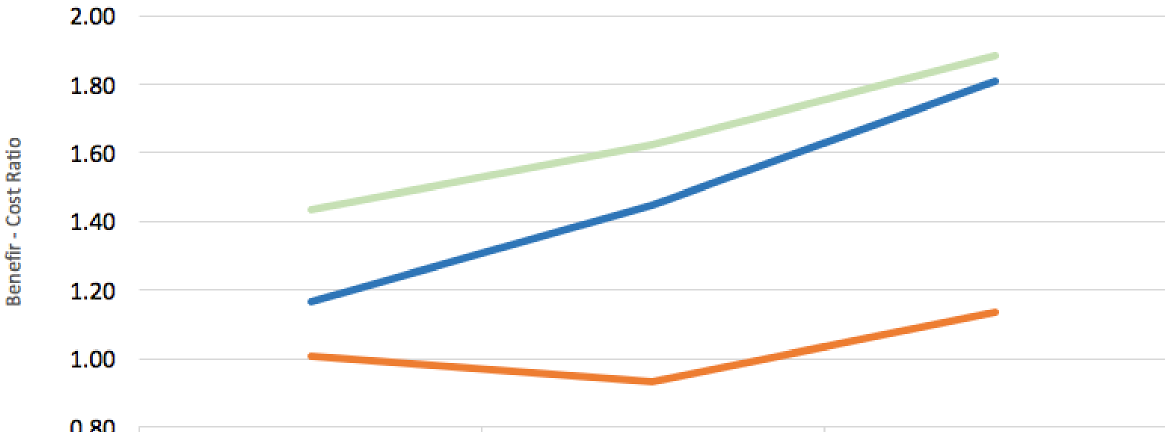
4.5 Sensitivity Analysis and alternative scenarios

During the sensitivity analysis, alternative scenarios will be developed examining the effect of specific parameters on the overall CBA performance of each demo case. According the required data for the calculation of potential benefits resulting from the implementation of SMILE installations, parameters with significant importance are considered the following ones:

- Lifetime of the project
- O&M costs
- Price of electricity
- Electricity consumption
- Price of thermal energy
- Thermal energy consumption covered by heat pumps

The selection of these specific parameters was based on the already calculated benefits. In the cases of Samsø and Madeira the most profitable benefit category is the reduction of electricity costs, hence there is a need to further examine the value deviations on price of electricity and total electricity consumption. In the case of Orkneys demonstrator, the most important benefit category, according to the results, is the reduced heating costs due to the implementation of heat pumps. Hence the price of thermal energy, as well as the contribution of heat pumps to the overall heating needs are important parameters that need to be examined. Finally, given the fact that the value for O&M costs was mostly based in certain assumptions, it is important to measure potential changes on the BCR of each demonstrator, for different O&M values.

Regarding the project’s lifetime, two additional scenarios were examined, increasing the lifetime to 20 and 25 years. The results of the Benefit-Cost Ratio fluctuations are presented in Figure 4-1.



	15 years	20 years	25 years
Samso	1.01	0.93	1.13
Madeira	1.43	1.63	1.88
Orkney	1.17	1.45	1.81

Figure 4-1. Cost-Benefit Ratio sensitivity analysis with the parameter of project's lifetime (15 years, 20 years, 25 years)

Increasing the project’s lifetime directly affects the equipment costs of each demonstrator site. Some components have lower lifetime hence repurchasing the same component is calculated on the overall capital expenditures. This fact affects Samsø demonstrator for the 20-years scenario, as in the sensitivity performs worse that the original 15 years scenario. This is due to the BESS equipment which is costly and has a lifetime of 15 years, hence it needs to be purchased twice over the span of 20 or 25 years. However, in the 25 years scenario the newly acquired equipment has enough time to generate more benefits, hence the 25 years scenario is more profitable than the baseline 15-years scenario. This is not the case for the Madeira and Orkneys demonstrators, which perform better both in the 20 and in 25 years’ scenarios. The overall capital expenditures increase around 30% for the 25 year scenario, however the overall benefits outweigh the total costs, subsequently improving the overall demos performance.

The examination of the additional parameters will occur while taking into account the minimum examined lifetime (15 years) since this scenario is the one where all demos perform better, according the previous analysis in Figure 4.1. A ±20% sensitivity analysis is considered and the results are summarized in Figure 4-2, Figure 4-3, and Figure 4-4.

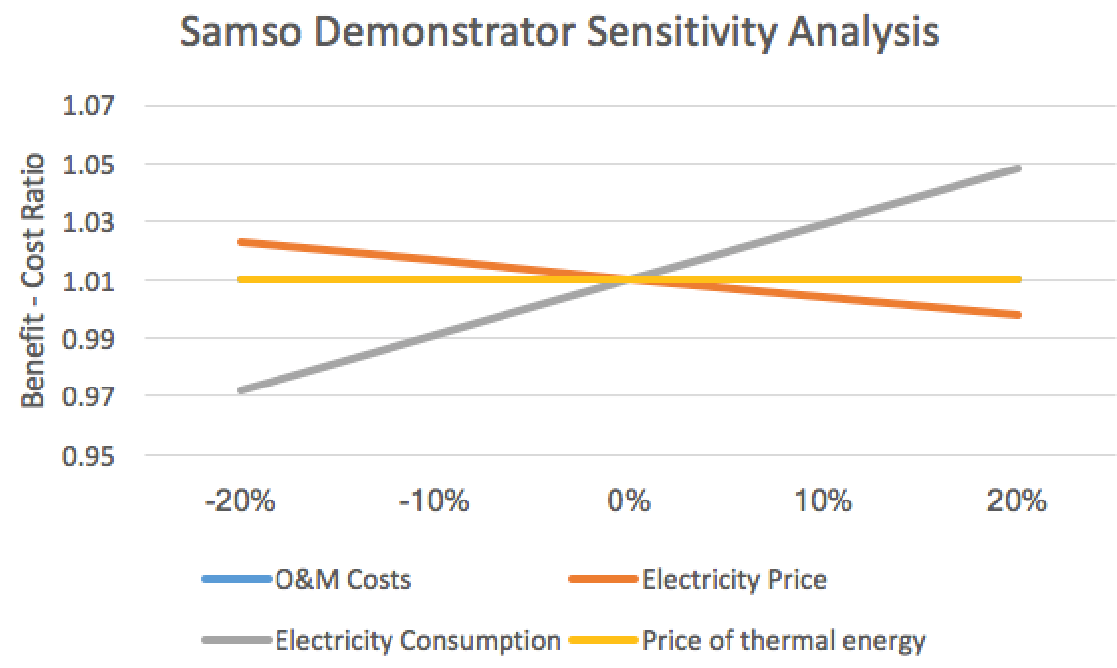


Figure 4-2. Samsø Demonstrator Sensitivity Analysis in various parameters (O&M Costs, Electricity Price, Electricity Consumption, Price of Thermal Energy)

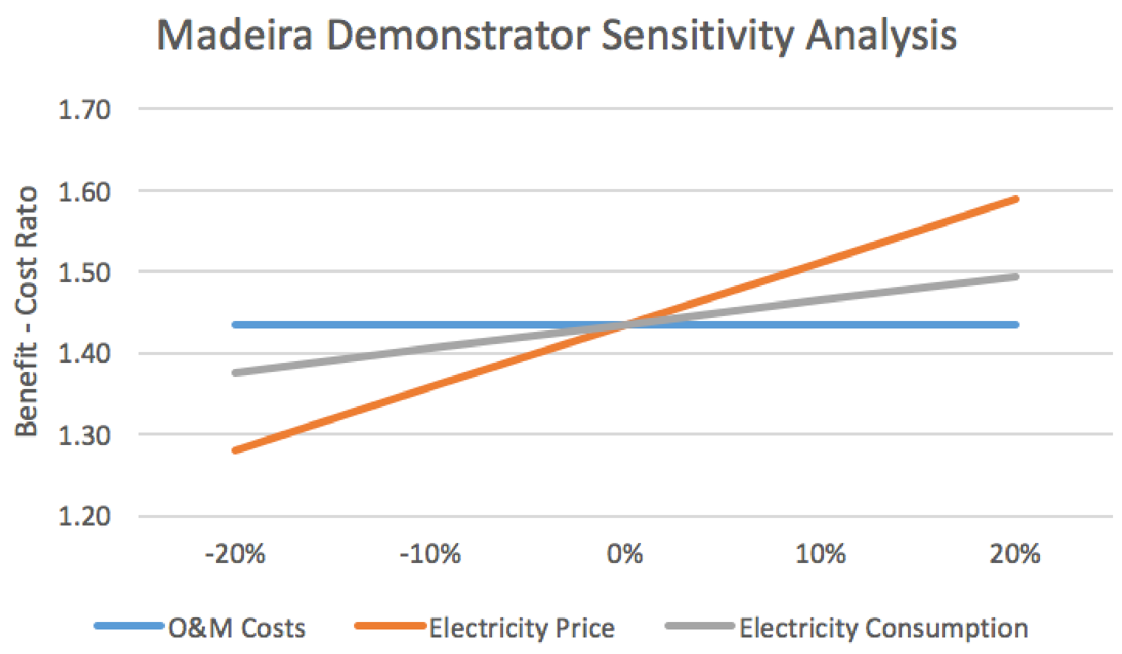


Figure 4-3. Madeira Demonstrator sensitivity analysis in various parameters (O&M Costs, Electricity Price, Electricity Consumption)

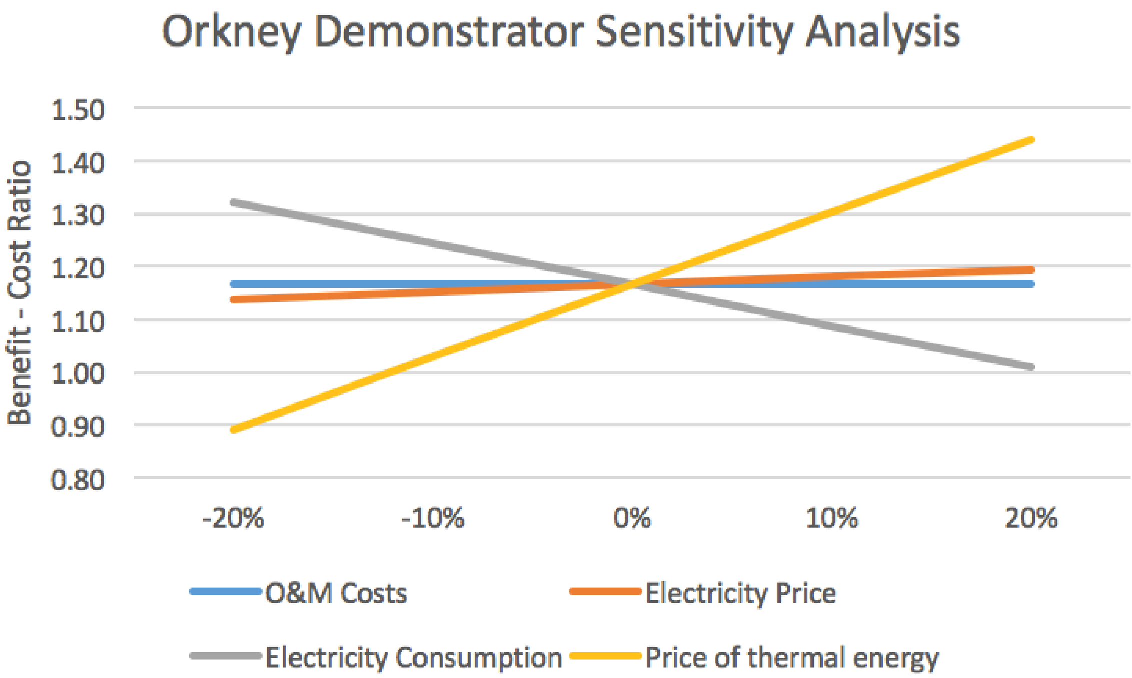


Figure 4-4. Orkney Demonstrator sensitivity analysis in various parameters (O&M costs, Electricity Price, Electricity Consumption, Price of thermal Energy)

The overall picture of the sensitivity analysis is that regardless of the changes in different parameters all demonstrators remain profitable, with the minor exception of Samsø and the parameter of electricity consumption, and Orkney with the parameter of price of thermal energy. Price of thermal energy is a major parameter, the one with the highest impact in the case of Orkney. The price of thermal energy subjects to changes quite often, so it is important to monitor the performance of the demo site. Due to the heat pumps installation, Orkneys demonstrator covers 100% of the heating needs. Subsequently, based on the selected benefits presented previously, an increase on the overall thermal energy price, leads to an increase of the total benefits from the SMILE installations, due to the costs being avoided because of the heat pumps. All other parameters do not appear to have significant effect on the overall performance of the benefit-cost ratio of the Orkney demo site.

In the Samsø demo site, the major parameter affecting the overall BCR is the electricity consumption. In the case that the overall electricity consumption is reduced by 20%, the BCR drops below 1. This is due to the fact that that Samsø demo site has achieved to reach lower overall dependence on the existing grid with PV and BESS installations. The more electricity consumed, the higher the benefits because less electricity cost is amounted to the grid operator. Every other parameter does not have significant contribution to the overall BCR.

In the Madeira demo case, the parameter affecting the most the overall benefit-cost ratio is the electricity price. Decreasing the electricity price from the traditional grid leads to lower BCR. This is due the benefit category of Reduced Electricity Costs, that take into account the electricity price. Reducing the overall electricity price, results in less profits in this specific benefit category. The remaining parameters do not have significant effect on the BCR of the Madeira demonstrator. The existing sensitivity analysis for the Madeira demo case does not include parameters regarding thermal energy since, Madeira has not implemented heat related installations (heat pumps). This scenario is examined separately for a lifetime of 15 years, while implementing heat pumps that cover from 25% to 100% of the total thermal energy needs (as in the case of Samsø and Orkneys). This means that in the examined scenarios the heat pumps have 25%, 50%, and 100% contribution to the total heating needs of the Madeira demonstrator. The results are summarized in Figure 4-5.

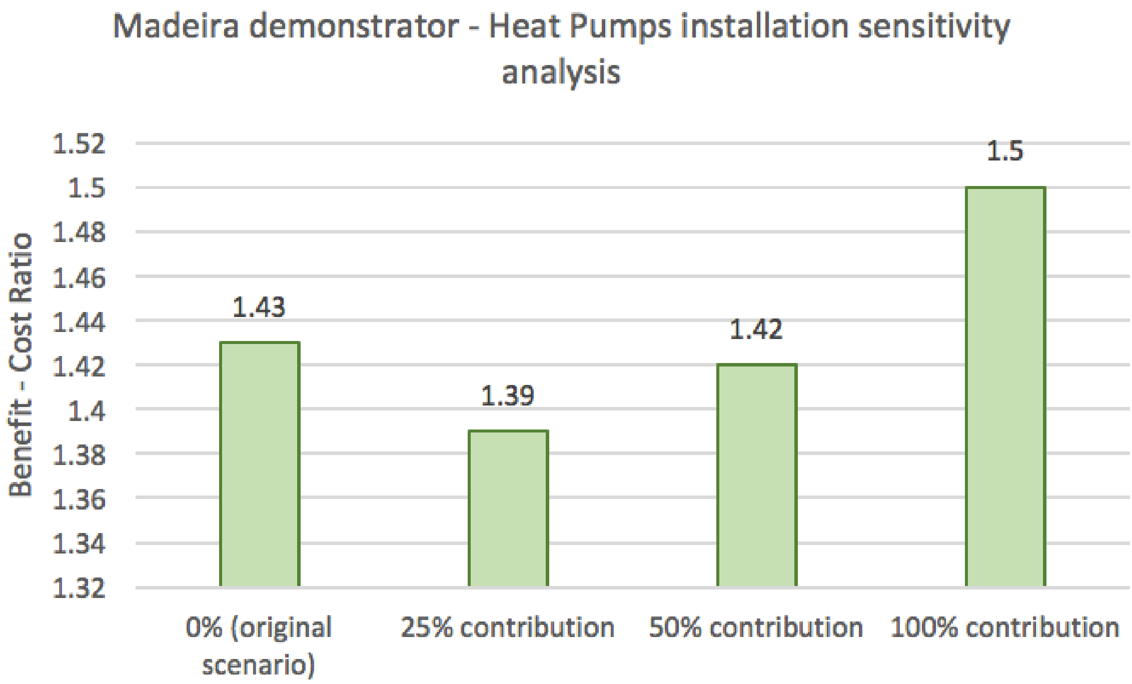


Figure 4-5. Madeira demonstrator - Heat Pumps contribution to the total heating demands (sensitivity analysis)

In order for the installation of heat pumps to be considered profitable for the Madeira demo case, only the scenario of 100% contribution to the overall thermal needs should be considered. This is due to the fact of the additional expenditures regarding the purchase of the heat pumps. However, even on the cases of 25% and 50% contribution, the overall benefit-cost ratio of the demonstrator is considered profitable.

5 Social CBA

5.1 Methodology

The Cost Benefit Analysis for each demonstrator is complimented with a Social CBA using the principles of Social Impact Assessment (SIA). A Social Impact Assessment is a process of research, planning and the management of social change or consequences (positive and negative, intended and unintended) arising from policies, plans, developments and projects [16]. The core focus of an SIA is on the important impacts of projects and developments beyond the impacts on natural resources. Examples of social impacts include (15):

- People's way of life – that is, how they live, work, play and interact with one another on a day-to-day basis.
- Their culture – that is, their shared beliefs, customs, values and language or dialect.
- Their community – its cohesion, stability, character, services and facilities.
- Their political systems – the extent to which people are able to participate in decisions that affect their lives, the level of democratization that is taking place, and the resources provided for this purpose.
- Their health and well-being – health is a state of complete physical, mental, social and spiritual well-being and not merely the absence of disease or infirmity.

From the listed examples above, it is clear that the SIA must look not only at social issues but also at the environmental impacts and their interactions. For example, if the planned project impacts the availability of water and land for local food production it also leads to social impacts, such as increases in food prices, the need to travel longer distances to buy and/or grow food.

In general, a SIA calls for close collaboration with community members, as well as other stakeholders and experts. This usually covers the following specific areas to identify impacts and mitigation measures (State of Queensland, 2013):

- Community and stakeholder engagement
- Workforce management
- Housing and accommodation
- Local business and industry content
- Health and community well-being.

The social impact assessment for the demo sites of SMILE project is based on the methodology developed by [17] "Handbook for Product Social Impact Assessment". The target of this methodology is to evaluate potential social impacts of a product or service throughout all of its lice cycle stages. This can be achieved by addressing three main objectives:

1. Make positive and negative impacts of products measurable and visible

Social impact assessment should flag both the social issues and the social benefits associated with a product. This can help steer programmes for performance improvement on identified hotspots as well as adding value to the product by highlighting positive social impacts.

2. Support decision-making and communication at product level

Primarily, Product Social Impact Assessment has to support the monitoring of product performance and subsequent internal communication and decision-making. At a later stage, it may also function as a tool for the company to support B2B communication and dialogue with external stakeholders, including potential regulatory discussions. Additionally, in a more advanced stage, it may also provide support for product marketing in B2B and B2C communication.

3. Contribute to overall sustainability assessment

Initially, Product Social Impact Assessment is a stand-alone tool to support social sustainability. Furthermore, as it is also consistent with the principles of environmental and economic assessments, it could be integrated into one overall sustainability assessment of a product.

The impact assessment used in the proposed methodology allows categorization in stakeholder's groups, relevant social topics, and performance indicators for each social topic. A schematic representation of the interrelationship between the aforementioned components is presented in Figure 5-1.

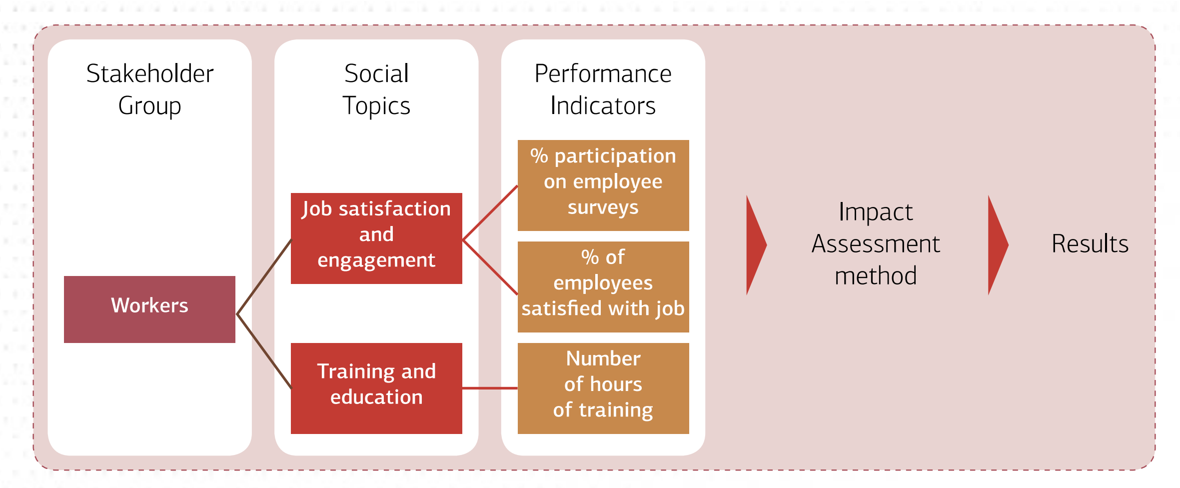


Figure 5-1 Key components of Social Impact Assessment methodology [17]

An identified stakeholder group could have several social topics and multiple performance indicators per social topic. Following this approach, specific questionnaires were developed for each demo site of the project. At first, three stakeholder categories were identified for all demo sites, based on their importance during the installation and use phase of the proposed SMILE solutions:

- Tech-providers - DSOs - Employees
- Community
- Customers

Following the selection of the specific stakeholders group, the developed questionnaires included specific social topics and questions for each demo site in order to evaluate their social impact. Following there is a presentation of the questions for each demo site.

Samsø (DK) demonstrator

The implemented solutions in Samsø demonstrator have potential interest in all aforementioned stakeholder categories, as new technologies, higher RES energy mixtures, grid operational solutions and policies are tested. Essential parts of the SMILE implemented solutions are the use of EV, the stability of the electricity network, as well as the promotion of the tourist sector, hence the developed questionnaire focuses on these issues.

Stakeholder Category: Tech-providers, DSOs, Employees

Employees	1	During the installation the demo site complied with regulations on workers' health and safety.
	2	Operators of the demo site are provided with safety equipment.
	3	Percentage of employees who are paid a living wage
	4	Percentage of employees who are training or have participated periodically in programmes aimed at capacity and skill development

DSOs	1	Is the pressure on the distribution network reduced due to the implementation of the new technologies?
	2	Does the DSO experience a reduction on maintenance or other costs for the network?

Technology providers	1	Have the technology providers benefited by reduced maintenance costs of equipment?
	2	Is there a noticeable and increased public interest regarding the new technologies

Stakeholder Category: Community

Health and Safety	1	Risks and impacts on community health and safety are regularly assessed and monitored.
	2	Proactive action to improve community health and safety is taken.

Employment	1	Number of new jobs created during the reporting period

Natural Environment	1	Disturbance on the natural environment of the marina and community acceptance

Community Engagement	1	The demonstrator has made attempts to engage with the local community addressing potential questions.
	2	Opportunities for community support are identified and appropriate programmes are implemented

Access to Resources	1	Percentage of the local community that gained access to the end product of the demo site.

Tourism	1	Has the implementation of the new scenario led to an increase in tourism?
	2	Has the implementation of the new scenario balanced the inconsistencies of energy demand?

Stakeholder Category: Customers

Health and Safety	1	The end product is safe for use
	2	A procedure is in place in the event of customer injury or property damage

Financial Benefits	1	Impact of the overall project to consumer's expenses.

Network consistency	1	Is the network consistent with the needs of every customer (boats, electric vehicles, service buildings)?
	2	Has the customers benefited from fewer electricity losses and power outages?

Madeira Demonstrator

As already mentioned in other deliverables, the Madeira DSO has a really difficult job, as it has to make a "small" grid both secure and sustainable. Furthermore, it is important to promote RES penetration in the existing network, hence promoting legislative changes. Furthermore, from a consumer standpoint, there is a need to reduce interruptions and bad power quality, but keeping a relatively low price. The developed questionnaires took into account all the potential issues the Madeira demonstrator faces and needs to address.

Stakeholder Category: Tech-providers, DSOs, Employees

Employees	1	During the installation the demo site complied with regulations on workers' health and safety.
	2	Operators of the demo site are provided with safety equipment.
	3	Percentage of employees who are paid a living wage
	4	Percentage of employees who are training or have participated periodically in programmes aimed at capacity and skill development

DSOs	1	Is the pressure on the distribution network reduced due to the implementation of the new technologies?
	2	Does the DSO experience a reduction on maintenance or other costs for the network?
	3	Is the quality of services delivered optimized with the implementation of new technologies?
	4	Is the DSO satisfied with the final price of the electricity?
	5	Can the DSO increase the share of RES in the electricity mixture?

Technology providers	1	Have the technology providers benefited by reduced maintenance costs of equipment?

Stakeholder Category: Community

Health and Safety	1	Risks and impacts on community health and safety are regularly assessed and monitored.
	2	Proactive action to improve community health and safety is taken.

Employment	1	Number of new jobs created during the reporting period

Natural Environment	1	Disturbance on the natural environment of the island and community acceptance

Community Engagement	1	The demonstrator has made attempts to engage with the local community addressing potential questions.
	2	Opportunities for community support are identified and appropriate programmes are implemented
	3	Did the DSO and the community argued for legislative change regarding the increase of the RES share?

Access to Resources	1	Percentage of the local community that gained access to the end product of the demo site.

Stakeholder Category: Customers

Health and Safety	1	The end product is safe for use
	2	A procedure is in place in the event of customer injury

Financial Benefits	1	Impact of the overall project to consumer's expenses.
	2	Given the specific features of the island, are the consumers satisfied with the final price of electricity?

Network sustainability	1	Have the consumers experienced less interruptions and bad power quality?

Orkneys (UK) demonstrator

In the case of Orkneys demonstrator, the most difficult task is on the hand of the DNO since there are a lot of changes that need to be implemented, covering more RES penetration, electric transportation, electric heating solutions etc. From a community standpoint, an important factor that needs to be addressed is the access to resources. Following the original plan 45 households were planned to have access to the new implemented solutions, and that needs to be examined. Finally, it is significant to examined the quality of provided power and the grid sustainability along with the final electricity price.

Stakeholder Category: Tech-providers, DNOs, Employees

Employees	1	During the installation the demo site complied with regulations on workers' health and safety.
	2	Operators of the demo site are provided with safety equipment.

	3	Percentage of employees who are paid a living wage
	4	Percentage of employees who are training or have participated periodically in programmes aimed at capacity and skill development

DNOs	1	Is the pressure on the distribution network reduced due to the implementation of the new technologies?
	2	Does the DNO experience a reduction on maintenance or other costs for the network?

Technology providers	1	Have the technology providers benefited by reduced maintenance costs of equipment?
	2	Is there a noticeable and increased public interest regarding the new technologies

Stakeholder Category: Community

Health and Safety	1	Risks and impacts on community health and safety are regularly assessed and monitored.
	2	Proactive action to improve community health and safety is taken.

Employment	1	Number of new jobs created during the reporting period

Natural Environment	1	Disturbance on the natural environment and community acceptance

Access to Resources	1	Percentage of the original target of 45 households with actual access to the new heating solutions
	2	Is there a plan to extend the access beyond the 45 households set as the original target?

Community Engagement	1	The demonstrator has made attempts to engage with the local community addressing potential questions.
	2	Is the community open towards a transition to EV use?
	3	Has the community mentioned changes regarding the heating comfort after the implementation of the new heating solutions?

Stakeholder Category: Customers

Health and Safety	1	The end product is safe for use
	2	A procedure is in place in the event of customer injury

	1	Impact of the overall project to consumer's expenses.

Financial Benefits	2	Is there a noticeable reduction on power outage since the implementation of new technologies?

For the interpretation of the results a scale based approach is implemented, as proposed by the methodology. In the scales-based approach, data are interpreted and scores are attributed to each life cycle actor in relation to a scale. The performance indicator is then calculated by aggregating the scores of the life cycle actors for which the performance indicator has been determined as relevant. Note that, if a performance indicator is not applicable to a life cycle actor, the criteria related to the performance indicator are not taken into account in the scale rating.

The scale allows the comparison of data with a reference, usually an international standard, an industry average, or even an improvement target set by the company. The proposed scale has 5 positions. Each position on the scale is a performance reference point, which is assigned a score ranging from -2 to +2 (Figure 5-2).

Performance Reference Points

+2 ideal performance
+1 intermediate positive performance
0 aligned with international standards
-1 intermediate negative performance
-2 non- acceptable performance

Figure 5-2 Scale-based reference points [17]

Referencing this scale-based approach, each question will lead to a total score for each social topic, followed by a total score for each stakeholder category. The calculation of social topic scores and stakeholders' scores, is highly recommended for communicating the impact assessment, since presenting only the performance indicators can confuse non-experts. The social topic scores can be multiplied by weighting factors that can be defined as a percentage of the weight assigned to the social topic score per stakeholder group. The weighting step for the SMILE case studies was developed taking into account the specific needs of each demonstrator, and it was subjected to a sensitivity analysis in order to examine potential fluctuations in the total social score. [17].

5.2 Social CBA Results

5.2.1 Samsø (DK) demonstrator

The questionnaire results for the Samsø demonstrator (based on the questionnaire presented in Chapter 5.1) are presented in Table 5.1.

Table 5.1 Samsø Demonstrator questionnaire results

Stakeholder category	Social Topic	Question	Answer	Score
Employees, DSOs and Technology Providers	***Employees***	During the installation the demo site complied with regulations on workers' health and safety.	Yes	1
		Operators of the demo site are provided with safety equipment.	No	-1
		Percentage of employees who are paid a living wage	All workers are paid at least the legal or industry minimum wage, with >=25% of workers paid a living wage	2
		Percentage of employees who are training or have participated periodically in programmes aimed at capacity and skill.	>75% workers are trained occasionally	1
	DSOs	Is the pressure on the distribution network reduced due to the implementation of the new technologies?	Yes	1
		Does the DSO experience a reduction on maintenance or other costs for the network?	No	-1
	Technology Providers	Have the technology providers benefited by reduced maintenance costs of equipment?	No	-1
		Is there a noticeable and increased public interest regarding the new technologies	Yes	1
Community	***Health & Safety***	Risks and impacts on community health and safety are regularly assessed and monitored.	Yes	1

		Proactive action to improve community health and safety is taken.	Yes	1
	Employment	Number of new jobs created during the reporting period	Number of new jobs created = number of jobs lost	0
	Natural Environment	Disturbance on the natural environment of the marina and community acceptance	Local community raised several complaints regarding natural environment disturbance.	-2
	Community Engagement	The demonstrator has made attempts to engage with the local community addressing potential questions.	Yes	1
		Opportunities for community support are identified and appropriate programmes are implemented	Yes	1
	Access to resources	Percentage of the local community that gained access to the end product of the demo site.	More than 25% of the local community has access	2
	Tourism	Has the implementation of the new scenario led to an increase in tourism?	No	-1
		Has the implementation of the new scenario balanced the inconsistencies of energy demand?	Yes	1
Customers	***Health & Safety***	The end product is safe for use.	Yes	1
		A procedure is in place in the event of customer injury or property damage.	Yes	1
	Financial Benefits	Impact of the overall project to consumer's expenses.	The project does not lead to less expenses.	0
	Network Consistency	Is the network consistent with the needs of every customer (boats, electric vehicles, service buildings)?	Yes	1
		Has the customers benefited from fewer electricity losses and power outages?	Yes	1

The total scores per stakeholder category for the Samsø demonstrator are presented in

Table 5.2. In order to calculate the scores per stakeholder, the sum score of each question is divided by the number of questions per stakeholder category. Samsø demonstrator exceeds in the Stakeholder category of consumers, which is mostly due to the fact that the SMILE implemented solutions helped with the consistency and sustainability of the network, reducing the power outages. The lowest score is on the stakeholder category of community, and these can be attributed to the fact that the local community has raised several complaints regarding the disturbance of the natural environment.

Table 5.2 Score results per stakeholder category for the Samsø demonstrator

Stakeholder Category	Score
Employees, DSOs and Technology Providers	0.375
Community	0.444
Customers	0.800

5.2.2 Madeira demonstrator

The questionnaire results for the Madeira demonstrator are presented in Table 5.3.

Table 5.3. Madeira Demonstrator questionnaire results

Stakeholder category	Social Topic	Question	Answer	Score
Employees, DSOs and Technology Providers	***Employees***	During the installation the demo site complied with regulations on workers' health and safety.	Yes	1
		Operators of the demo site are provided with safety equipment.	Yes	1
		Percentage of employees who are paid a living wage	All workers are paid at least the legal or industry minimum wage, with >=25% of workers paid a living wage	2
		Percentage of employees who are training or have participated periodically in programmes aimed at capacity and skill.	<50% of workers are trained occasionally	-1
	DSOs	Is the pressure on the distribution network reduced due to the implementation of the new technologies?	No	-1
		Does the DSO experience a reduction on maintenance or other costs for the network?	No	-1

		Is the quality of services delivered optimized with the implementation of new technologies?	Yes	1
		Is the DSO satisfied with the final price of the electricity?	Yes	1
		Can the DSO increase the share of RES in the electricity mixture?	Yes	1
	Technology Providers	Have the technology providers benefited by reduced maintenance costs of equipment?	No	-1
Community	***Health & Safety***	Risks and impacts on community health and safety are regularly assessed and monitored.	N/A	0
		Proactive action to improve community health and safety is taken.	N/A	0
	Employment	Number of new jobs created during the reporting period	Number of new jobs created > number of jobs lost. Number of new jobs created < 2% of total number of jobs in the company or facility.	1
	Natural Environment	Disturbance on the natural environment of the marina and community acceptance	The issue of natural environment disturbance was never discussed with the local community.	0
	Community Engagement	The demonstrator has made attempts to engage with the local community addressing potential questions.	Yes	1
		Opportunities for community support are identified and appropriate programmes are implemented	Yes	1
		Did the DSO and the community argued for legislative change regarding the increase of the RES share?	No	-1
	Access to resources	Percentage of the local community that gained access to the end product of the demo site.	Local community currently has no significant access, but will in the foreseeable future.	0
Customers	***Health & Safety***	The end product is safe for use.	Yes	1

		A procedure is in place in the event of customer injury or property damage.	No	-1
	Financial Benefits	Impact of the overall project to consumer's expenses.	The project does not lead to less expenses.	0
		Given the specific features of the island, are the consumers satisfied with the final price of electricity?	No	-1
	Network Sustainability	Have the consumers experienced less interruptions and bad power quality?	No	-1

The total score per stakeholder category, and the total Social Score for the Madeira demonstrator are presented in Table 5.4.

Table 5.4. Score results per stakeholder category for the Madeira demonstrator

Stakeholder Category	Score
Employees, DSOs and Technology Providers	0.400
Community	0.250
Customers	-0.400

5.2.3 Orkneys (UK) demonstrator

The questionnaire results for the Orkneys demonstrator are presented in Table 5.5.

Table 5.5 Orkneys Demonstrator questionnaire results

Stakeholder category	Social Topic	Question	Answer	Score
Employees, DSOs and Technology Providers	***Employees***	During the installation the demo site complied with regulations on workers' health and safety.	Yes	1
		Operators of the demo site are provided with safety equipment.	Yes	1
		Percentage of employees who are paid a living wage	All workers are paid at least the legal or industry minimum wage, with >=25% of workers paid a living wage	2
		Percentage of employees who are training or have participated periodically in programmes aimed at capacity and skill.	<50% of workers are trained occasionally	-1

	DNOs	Is the pressure on the distribution network reduced due to the implementation of the new technologies?	No	-1
		Does the DSO experience a reduction on maintenance or other costs for the network?	No	-1
	Technology Providers	Have the technology providers benefited by reduced maintenance costs of equipment?	No	-1
		Is there a noticeable and increased public interest regarding the new technologies	Yes	1
Community	***Health & Safety***	Risks and impacts on community health and safety are regularly assessed and monitored.	No	-1
		Proactive action to improve community health and safety is taken.	N/A	0
	Employment	Number of new jobs created during the reporting period	Number of new jobs created = number of jobs lost	0
	Natural Environment	Disturbance on the natural environment of the marina and community acceptance	Local community has complimented the installation and there are no worries regarding natural environment disturbance	2
	Community Engagement	The demonstrator has made attempts to engage with the local community addressing potential questions.	No	-1
		Is the community open towards a transition to EV use?	Yes	1
		Has the community mentioned changes regarding the heating comfort after the implementation of the new heating solutions?	Yes, positive changes.	1
	Access to resources	Percentage of the original target of 50 households with actual access to the new heating solutions	75%	1

		Is there a plant to extend the access beyond the 50 households set as the original target?	No	-1
Customers	***Health & Safety***	The end product is safe for use.	Yes	1
		A procedure is in place in the event of customer injury or property damage.	No	-1
	Financial Benefits	Impact of the overall project to consumer's expenses.	The project does not lead to less expenses.	0
	Network Consistency	Is there a noticeable reduction on power outage since the implementation of new technologies?	No	-1

The total score per stakeholder category, and the total Social Score for the Orkneys demonstrator are presented in Table 5.6.

Table 5.6 Score results per stakeholder category for the Orkneys demonstrator

Stakeholder Category	**Score**
Employees, DSOs and Technology Providers	0.125
Community	0.111
Customers	-0.250

Implementing the same weighting factor for each stakeholder category, the final total social score for each demonstrator is presented in Figure 5-3, not in a comparative manner, but as an overall picture of the social CBA study. The Total Social Score for each demonstrator site is a unique number and it is not directly compared to the scores of other demonstrator sites due to the different socioeconomic environments, needs, and conditions of each country. The applied methodology served as a mean to quantify potential social impacts through a set of indicators described in the available literature, however certain assumptions were implemented, hence making the final results debatable and in need of constant monitoring and update.

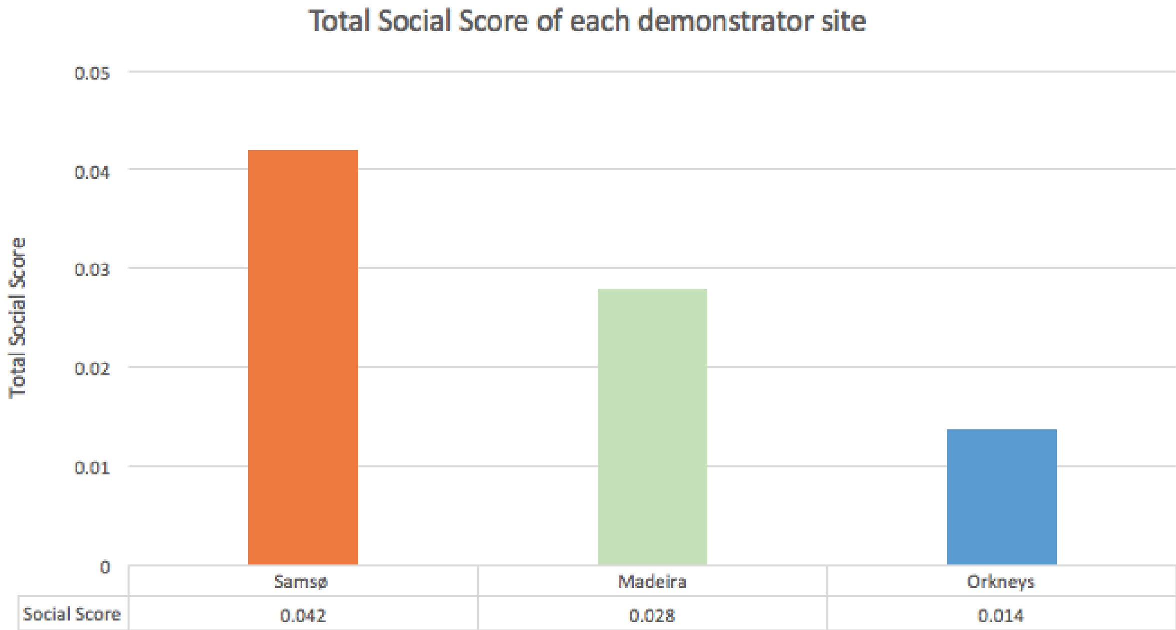


Figure 5-3 Social Score for each demonstrator

5.3 Sensitivity Analysis and Discussion

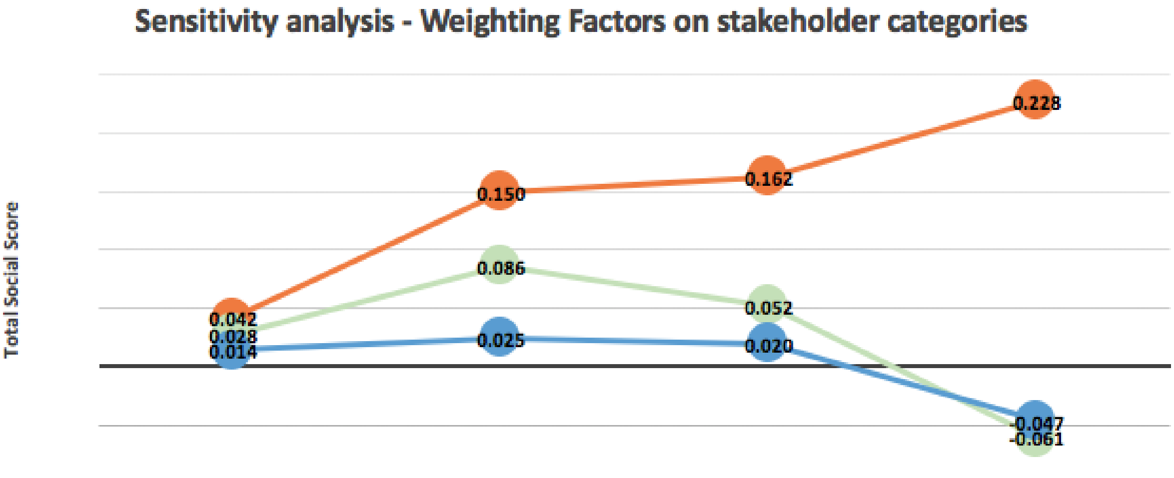
A range of scenarios with different weighting factors for each stakeholder category was considered, in order to perform a sensitivity analysis for the total social score of each demonstrator . Furthermore, sub-scenarios with weighting factors on the social topics of each stakeholder are presented as well.

The different weighting scenarios are presented in Table 2.1.

Table 5.7 Weighting scenarios on stakeholder categories - Sensitivity analysis

Stakeholder Category	Scenario 1	Scenario 2	Scenario 3	Baseline
Employees, DSOs, Technology providers	70%	15%	15%	33.3%
Community	15%	70%	15%	33.3%
Consumers	15%	15%	70%	33.3%

The results of the sensitivity analysis are presented in Figure 5-4.



	Baseline	Scenario 1	Scenario 2	Scenario 3
Samso	0.042	0.150	0.162	0.228
Madeira	0.028	0.086	0.052	-0.061
Orkneys	0.014	0.025	0.020	-0.047

Figure 5-4 Sensitivity analysis - Weighting factors on stakeholder categories

In the case of Samsø demonstrator, the Scenario 3 with 70% weighting on the consumers' stakeholder category is the one providing a higher social score. In this stakeholder category the Samsø demonstrator presented high score and this fact is attributed to the consistency of the network after the implemented solutions. With the implementation of SMILE project, the network is more consistent with the needs of every customer (boats, electric vehicles, service buildings). Moreover, the customers have significantly benefited from the fact that are fewer power outages and energy loses in the network.

In the case of Madeira demonstrator, the highest total social score appears to be in the Scenario 1, in which the stakeholder category of "Employees, DSOs, and Technology Providers" has the highest weighting factor. In general, the overall score of the Madeira demonstrator could be significantly improved by focusing a little more on issues regarding the local community and the consumers. As of now the network has not presented the expected stability and sustainability, however due to the COVID-19 pandemic the metering data from each demo is not yet available, hence they were not quantified as potential benefits that might prove to be beneficial for the overall performance of the demonstrator. Specifically, according to the relevant information provided by the partner, the data regarding variation in electricity consumption due to the implementation of EVs and smart charging are not available, hence not quantified in the calculations. The integration of these additional information will potentially prove the sustainability of the network, subsequently improving the performance on the stakeholder category of the local community and consumers.

Finally, in the case of Orkneys demonstrator, the highest total social score appears to be in the Scenario 1, with 70% weighting factor on the Employees, DSOs, and Technology Providers stakeholder category. One of the main objectives of the Orkneys demonstrator is to enhance the current electricity generation system by implementing more generators (wind turbines) supporting the operation of the grid, turning it from semi-smart to fully smart, so as to maximize its existing assets. This objective aims mostly towards the specific stakeholder's category; hence the results of the Social CBA sensitivity analysis are promising towards that end. However, there is still the need to address the relatively low performance on the consumer's stakeholder category. It would be useful for the demonstrator to implement a safety procedure in case of equipment failures, as well as find a way to eliminate potential power outages on the network, in order to achieve higher total social score in general.

Besides the sensitivity analysis of the stakeholder categories, it was deemed important to examine the potential effects of specific social topics. Provided the objectives of each demonstrator, the social topics of DSOs (from the stakeholder category Employees, DSOs, and Technology providers), the Natural Environment (from the stakeholder category Community), and the Financial Benefits (from the stakeholder category of Consumers), were the ones selected as the most influential, hence these are the ones that will have a higher weighting factor. Specifically, based on the number of social topics in each stakeholder category, the social topic of DSOs ends up with a weighting factor of 0.7, the social topic of Natural Environment with a weighting factor of 0.5, while the social topic with a weighting factor of 0.7. The results of this sub-scenario compared to the baseline social score are presented in Figure 5-5.

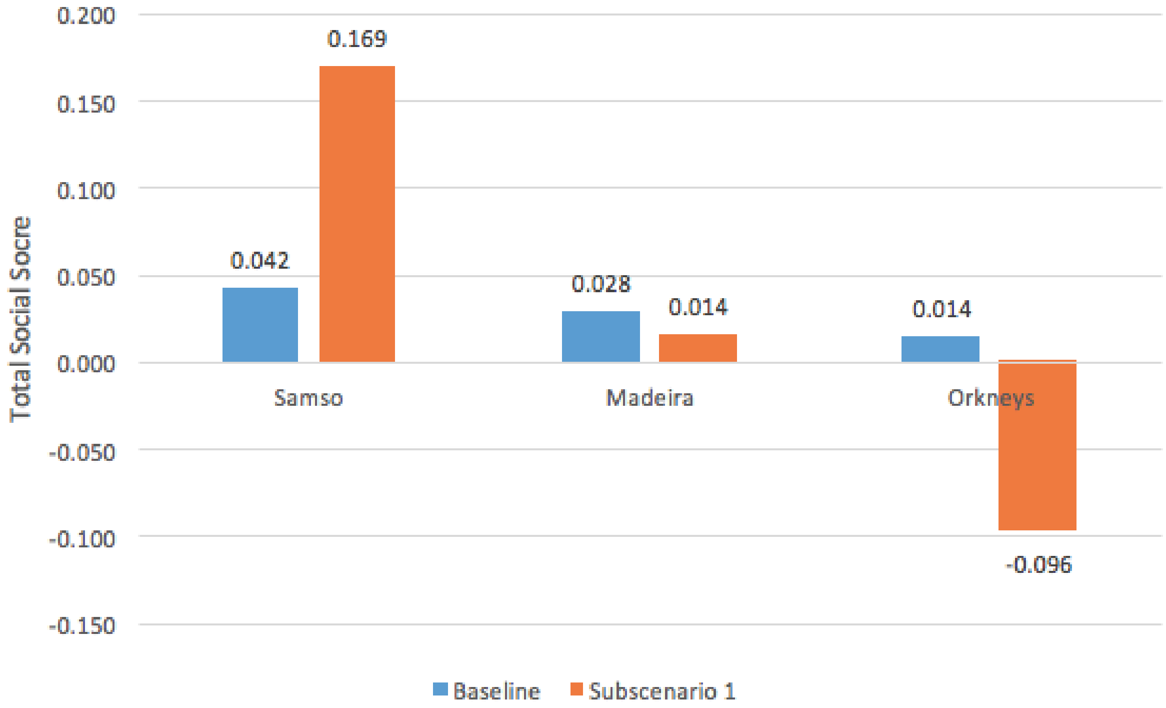


Figure 5-5 Sensitivity analysis on the Total Social Score with weighting factors on different social topics.

By applying these weighting factors on each demonstrator site, it is noticeable that Samsø is the only demonstrator that presents better results compared to the Baseline scenario, while Madeira and Orkneys presents a decline on the total score. This is mostly attributed to the social topic of DSOs. Samsø demonstrator responded in the questionnaires that they already experience less pressure on the distribution network due to the implementation of the new technologies, which is not the case for the Orkneys or the Madeira demonstrator. However, as already mentioned, the total social score of each demonstrator site is not directly comparable with one another due to completely different socioeconomic circumstances on each country.

6 Conclusions

During this study a comprehensive Cost Benefit Analysis (CBA) for the implemented solutions of the SMILE project regarding the operation of smart grids was performed. The CBA was complemented by the conduction of Social CBA based on the principles and framework of Social Life Cycle Assessment. The methodology selected for the CBA of the SMILE project demo sites, was based on the guidelines/general approach proposed by the JRC Reference Report, following a three step approach:

1. Define boundaries and set parameters (baseline scenario and SMILE scenario)
2. Determine Costs and Benefits - Perform the CBA
3. Perform sensitivity analysis

The data needed for the calculation of costs and benefits, as well as for the definition of baseline and SMILE scenarios, were acquired through the relevant partners and the available literature. The required costs that were taken into account were equipment purchase and installation costs, operation and maintenance costs, and miscellaneous externalities and environmental costs. The benefit categories were selected based on the available literature regarding CBA of smart grid projects, with necessary modifications in order to correspond even further with the demo sites, and their specific needs, under examination. Questionnaires were developed for the partners to provide data necessary for the CBA analysis, quantifying parameters relevant to the calculations of the benefits.

The CBA analysis results were based on the calculation of two indexes: Net Present Value (NPV) and Benefit-Cost Ratio (BCR). The results of the CBA analysis show that the implementation of SMILE proposed solutions leads to benefits that outweigh the costs for a lifetime of 15 years, since the Benefit-Cost Ratio of every demonstrator exceeds the value of 1. Regarding Samsø demonstrator, the most profitable benefit category is the reduction of electricity costs leading to a significant amount of profit calculated at around 188,000 € for the lifetime of the project. In Madeira case, reduced electricity costs is the most profitable benefit category as well, leading to an overall benefit of 118,390 € during the project's lifetime. This is due to the fact that the electricity consumption comes from the SMILE implemented solutions instead of the existing grid. Finally, in Orkneys case, the main profit derives from the benefit category of reduced heating cost, due to the implementation of heat pumps, leading to a benefit of around 3,790,000 €. Madeira demo site, does not include heat related installations, which are the focal point of benefits for the other two demonstrators. The possible implementation of heat pumps in the Madeira demonstrator is examined during the sensitivity analysis, in order to identify further benefits for the demonstrator.

Despite the overall good performance of each demonstrator, there are benefit categories that require further focus since they cause more costs after the implementation of SMILE solutions. Overall, all three demonstrators should figure out a way to improve their performance, reduce electricity losses, and facilitate the sustainability of the electricity network.

The sensitivity analysis included the examination of further parameters, with high impact on the benefits calculation, such as the lifetime of the project, electricity and thermal energy price, as well as electricity consumption. Overall, for Samsø demo site the parameter of electricity consumption is the one with the highest impact on the overall BCR performance. In Orkney demo site the parameter with the highest impact on Benefit-Cost Ratio, is the price of thermal energy. Due to the installed heat pumps, an increase on the overall thermal energy price, leads to an increase of the total benefits from the SMILE installations, due to the costs being avoided because of the heat pumps. Regarding the Madeira demonstrator, the most important parameter affecting the Benefit-Cost Ratio is the electricity consumption, as in the case of Samsø. This is due to the fact reducing the overall electricity consumption, results in less profits in the benefit category Reduced Electricity Costs.

Regarding Social Cost Benefit Analysis, relevant questionnaires were prepared and shared among the demo operators. Each demonstrator received a questionnaire targeted to its specific needs and characteristics. The Social CBA study focused on three main stakeholder categories:

- Employees - DSOs - Technology Providers
- Community
- Customers

For each stakeholder category, a Social Score was calculated. Based on these three social scores, applying a weighting factor, the Total Social Score for each demo site was calculated. It is important to notice that the Total Social Scores of the demonstrators are not directly comparable to one another, due to the specific needs and characteristics of each demo site, as well as due to the different circumstances on the countries of implementation. In the sensitivity analysis performed for the Social CBA study, several weighting factors were taken into account, with specific focus on stakeholder categories. Samsø demo site Total Social Score presented its highest value in the scenario where the highest weighting factor was given to the stakeholder category of Consumers. On the other hand, both Madeira and Orkneys demo sites had highest Total Social Score when the stakeholder category of Employees - DSOs - Technology Providers had the highest weighting factor. A conclusion resulting from the Social CBA study is that all three demo sites need to invest more in the community, by approaching their local communities and joining efforts to achieve their goals of increasing RES share, facilitating the implementation of the new technologies etc. It is important to notice that the completion of data and the calculation of the results for the Social LCA study are based on some assumptions and on premature operation status of the demo sites, hence further analysis and validation would provide more sufficient and objective results.

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