Energy market recommendations

Smart Island Energy Systems - H2020 Project SMILE Deliverable 8.4

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Publication date:
2021

Document Version
Accepted author manuscript, peer reviewed version

H2020-LCE-2016-2017

EUROPEAN COMMISSION

European Climate, Infrastructure and Environment Executive Agency (CINEA)

Grant agreement no. 731249

SMILE

Smart Island Energy Systems

Deliverable D8.4
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Document Details

Due date	30-04-2021
Actual delivery date	
Lead Contractor	AAU Plan (Aalborg University, Department of Planning)
Version	Final rev0
Prepared by	Hannah Marczinkowski (AAU Plan)
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Reviewed by	Rina Consulting S.p.A.
Dissemination Level	Public

Project Contractual Details

Project Title	Smart Island Energy Systems
Project Acronym	SMILE
Grant Agreement No.	731249
Project Start Date	01-05-2017
Project End Date	31-10-2021
Duration	54 months

The project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 731249

Table of Contents

Keywords, Acronyms

AAU	Aalborg University
ADSCR	Average debt service coverage ratio
BESS	Battery Energy Storage System
BMS	Battery Management System
CEEP	Critical Excess Electricity Production (EEP above the transmission line capacity)
CES	Community Energy Scotland
CFSR	Climate Forecast System Reanalysis (Weather data)
CHP	Combined Heat and Power plant
D8.X	Deliverable X from WP 8
DH	District Heating
DHC	District Heating and Cooling
DSM	Demand Side Management
DSO	Distribution System Operator
EEM	Electricity Company of Madeira (Empresa De Electricidade Da Madeira Sa)
EEP	Excess Electricity Production
EMS	Energy Management System
ESG	Environmental, Social and Governance
EPs	Equator Principles
EBRD	European Bank for Reconstruction and Development
ELENA	European Local Energy Assistance
EIB	European Investment Bank
EV	Electric Vehicle
GHG	Greenhouse Gases
GEFF	Green Economy Financing Facility
IRR	Internal Return Rate
IFIs	International Financial Institutions
JP	Jet Petrol
LPG	Liquefied Petroleum Gas
Li-on	Lithium-ion
MERRA	Modern-Era Retrospective analysis for Research and Applications (Weather data)
NESOI	New Energy Solutions Optimised for Islands
NPV	Net Profit Value
PCM	Phase-change material
PES	Primary Energy Supply
PF4EE	Private Finance for Energy Efficiency
PP	Power Plant
PV	Photovoltaic
RE	Renewable Energy
RAM	Região Autónoma da Madeira
SPV	Special Purpose Vehicle
TEG	Technical Expert Group
TES	Thermal Energy Storage
TSO	Transmission system operator
V2G	Vehicle To Grid
VDP	User Datagram Protocol
WP	Work Package

1 Introduction

The Smart Island Energy System (SMILE) combines a number of partners to investigate the project pilot islands Samsø in Denmark, Orkney in the United Kingdom and Madeira in Portugal and their ways of becoming carbon neutral through renewable energy (RE) and smart technology demonstration. While local conditions on these islands differ widely, the investigation covers similar technical and non-technical solutions, such as demand response, smart grid functionalities, storage and energy system integration. The demonstration includes – in line with the transition to high-RE shares – so-called smart technologies, such as battery electricity storage systems (BESS), power-to-heat, power-to-fuel, electric vehicles (EVs), electricity stored aboard boats, aggregator approach to demand side management (DSM) and predictive algorithms.

In this report, we present the outcome of *Task 8.4: Energy market design structures to support the transition to high-RE energy systems in Orkney, Samsø and Madeira*. Task 8.4 and the corresponding Deliverable 8.4 are part of the work package (WP) 8 of the SMILE project.

The present report continues work from related task, deliverables and resulting scenarios in previous Deliverable 8.2 [1], [2], which are elaborated here in the focus of energy market design, hence, how the scenarios can be implemented. Chapter 2 presents the context of the report through a review of WP8 as well as its relation to the other deliverables and related work. Here, also relevant work in relation to Task 8.4 as well as the energy market design approach is presented. Chapter 3 evaluates the energy market structures for each island individually and finds transcendent recommendations. Chapter 4 reflects on support mechanism for the promotion of the deployment of RE. Chapter 5 summarizes the presented evaluation and concludes the report.

2 Clarifications

This chapter presents clarifications that are necessary for a full understanding of this report. Therefore, a review of WP8 with its objectives and tasks is performed, including a summary of submitted deliverables and work in relation to this. The latter introduces the approaches taken for D8.4 and Section 2.2 elaborates on the methodology used for this report.

2.1 Review for energy market task

Below is a short recap of the related WP8 in the SMILE project, including a review of the preceding deliverables and research done, including references to important literature. This is used as basic understanding as it is influencing the next section on Energy market design approach and the following Chapters 3: Energy market structures to support the transition to high-RE systems and Chapter 4: Support Mechanisms for Energy Transition of Islands.

2.1.1 Review of Work Package 8 (WP8)

Within the frame of the SMILE project, the main goal of WP8 is to analyse and present the pilot islands' energy systems and the impacts, strategies and market designs associated with the project. The main objective of WP8 is to investigate potential development pathways towards high-RE for the three pilot islands taking into consideration the energy systems' impacts from the demonstration projects and their role in such high-RE scenarios. For this, the technical solutions demonstrated – from production, over conversion and storage, to demand – are taken into account. Besides these technical energy system analyses, the WP investigates the related energy market structures and policy strategies that impact and are impacted by the transition process in the three pilot islands.

The objectives of WP8 are achieved through meeting the following Tasks:

- 8.1: Establishment of reference energy systems simulations models of the three pilot islands (Deliverable submitted January 2018 [3])
- 8.2: Establishment of medium term (10-15 years) high RE scenarios for the three pilot islands (Deliverable submitted December 2018 [2])
- 8.3: Power loss management of minutes-based energy outages in the distribution grid of the three islands, with simulation tools (Deliverable submitted April 2021)
- 8.4: Establishment of recommendations for market design structures to support the transition to high-RE systems in the three pilot islands (this report, submitted April 2021)
- 8.5: Establishment of policy strategies to support the transition to high-RE systems in the three pilot islands (Deliverable submitted April 2021)

Further information and related documents of WP8 can be found on the SMILE website [4]: www.h2020smile.eu/press-downloads/ and on The Community Research and Development Information Service (CORDIS) website [1]: https://cordis.europa.eu/project/id/731249/results

While the first two deliverables cover the technical energy systems' aspects, the following work elaborates on the contextual aspects of market and policy analysis. Task 8.3 is running parallel and independent, based on data gathering and scenario development in Tasks 8.1 and 8.2. Also, this work of Task 8.4 is based on the modelling work done in Tasks 8.1 and 8.2. Especially, with the changes envisioned in Task 8.2, Task 8.4 investigates, on the one hand, how the transition may be supported or even thwarted by present energy market structures and, on the other hand, establishes recommendations for potential changes in the energy market structures that better support the transitions. Unlike the previous tasks, this task is not split up into separate tasks for the three pilot islands; rather, recommendations are sought that transcends the different circumstances given by the three pilot project islands. However, inputs from all demonstration islands are influencing Task 8.4, and all of them providing relevant contribution to Task 8.5.

2.1.2 Review of Deliverables

Since Task 8.4 is built upon the preceding tasks in WP8, a review of both D8.1 and D8.2 follows. Details on the modelling tool, data used and results obtained can be found in the corresponding deliverables.

Overall, the technical energy system analyses present the current and potential future energy system set-ups of all demonstrator islands, including all energy sectors (electricity, heating, transport, industry). While D8.1 focuses on the energy systems of 2014/2015, D8.2 focuses on the short and medium-term changes by 2022 and 2030, as seen in 2018.

Created in 2017, the data available for D8.1 and deemed suitable for either 2014 or 2015 resulted in the reference energy system models for Samsø, Orkney and Madeira Island. While the data was best suitable for 2014 for the two latter islands, Samsø's model is made based on 2015 data. Besides including all sectors, also the supply, conversion and demand sides are included and presented through the hour-based modelling tool EnergyPLAN [5]. The models include local characteristics, not just regarding the availability of wind potential and solar radiation, but also technologies and fuels most suitable and best employed in each island.

In D8.1, hence, the reference energy systems present the 'current' situation with its potentials and weaknesses in all the above-mentioned areas. In detail, the demonstration islands vary not just in population numbers, but also in electricity, heating and transport demand per capita. These sectors each depend on the climatic region, geography, cultural differences and local possibilities, resulting in in large variations between the islands. Samsø, for example, has a large biomass use, while Orkney produces a majority of heat from electric devices and Madeira's listed heat production focusses on gas. Regarding RE share, the reference energy systems show that Samsø provides 60% of its energy with local RE, Orkney 17% and Madeira Island 11%. The remaining energy supply in all three cases is fossil fuel-based. With the option of import/export, Samsø is currently modelled to export 78% of its local RE, while still requiring imports during low-wind high-demand hours. Also, Orkney is overproducing, resulting in a 32% export share of local production, while in reality a large share is also curtailed. For Madeira, where no transmission cable to the mainland exists, the lowest RE share and highest curtailment rates are to be expected. Overall, D8.1 indicates the need for better integration of locally produced energy to supply electricity, heating, cooling and transport needs sustainably, leading to D8.2.

Task 8.2 takes its starting point in the reference models developed in Task 8.1. From there, future scenarios are developed which include the technical and non-technical solutions demonstrated in the SMILE islands, including demand response, smart grid functionalities and storage, and energy system integration. Furthermore, potentially a larger deployment of the demonstration projects is addressed and, in general, a shift from energy systems relying on fossil fuels to energy systems relying highly or exclusively on RE. The focus of these scenarios is on the short-term, however in order to ensure that short-term measures are aligned with longer-term requirements, a medium-term perspective is also addressed. The outcome is a collection of scenarios for Samsø, Orkney and Madeira for the years 2022 and 2030.

While not only the SMILE technologies are evaluated, also a long-term focus is applied, resulting in additional technological advances and changes in the energy system, that ensures the transition to high RE shares for all islands in the long run. Along these lines, D8.2 introduces the three transition phases to 100% RE systems and a categorization of the islands within. The final target of these phases is characterized by the full transformation into 100% RE-based systems, where complex comparison of various technologies requires balance, sector integration, and optimized biomass utilization, which is based on research conducted at Aalborg University [6]. Furthermore, for islands, this is characterized by increased self-sufficiency. Hence, D8.2 concludes with a possible RE share of 85%, 38% and 31% by 2030 for Samsø, Orkney and Madeira Island respectively. However, this entails a better integration of local resources, technologies and demands. With increased electricity demand in the heating and transport sector, additional RE capacity, but also optimal utilization is required. While the SMILE solutions address this to some extent, the presented report of D8.4 continues the essential energy market alignment with the energy system models and scenarios.

While Task 8.4 investigates how this transition may be supported by present energy market structures, Task 8.5 relates to the corresponding policy strategies to support this for the demonstration islands. Hence, D8.5 relates to both the technical models and the energy market structures suggested. The deliverable is developed in parallel to this report as well as submitted simultaneously. This concludes WP8.

2.1.3 Related work and research approach

In relation to the work behind Task 8.1 and 8.2, the following research (**Error! Reference source not found.**) has been carried out by the WP lead partner. The overview highlights the importance of impact analyses carried out for the demonstration islands.

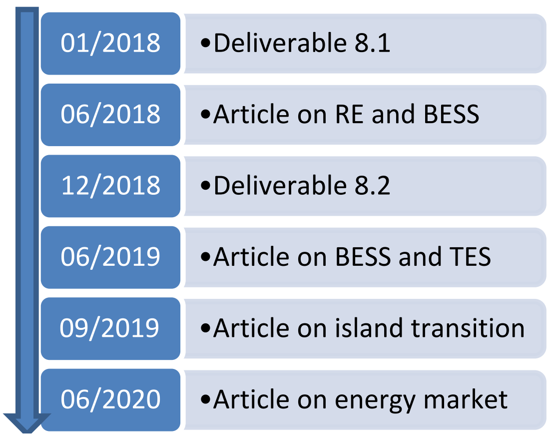

Figure 1: Research carried out in relation with Task 8.1 and 8.2

During the preparation and finalisation of D8.1 and the beginning of D8.2, research on RE and BESS types was made for the case study of Samsø, one of the demonstration islands. While the findings apply to other islands as well, the relevance of and for SMILE islands is shown. The research highlights the role of consumer engagement for optimal use of local RE production and storage. The research was presented at the 13th SDEWES conference[1] in Croatia and published in *Energy* (vol. 152) in June

[1] International Centre for Sustainable Development of Energy, Water and Environment Systems https://www.sdewes.org/

2018 under the title *"Residential versus communal combination of photovoltaic and battery in smart energy systems"* [7].

Furthermore in relation to the SMILE tasks, BESS was compared to TES in relation to balancing fluctuating electricity most efficiently, resulting in research presented at the 14th SDEWES conference in Italy and published in *Energy* (vol. 175) in May 2019 with the title *"Evaluation of electricity storage versus thermal storage as part of two different energy planning approaches for the islands Samsø and Orkney"* [8]. The research showed the benefits of power-to-heat technology in combination with thermal storage over electricity storage when used to balance fluctuating RE in island energy system.

Concluding D8.2, research was presented in *Energies* (vol. 12) in September 2019 with the title *"Transitioning Island Energy Systems—Local Conditions, Development Phases, and Renewable Energy Integration"* [9]. By evaluating smart technologies on all demonstration islands, the importance of self-sufficiency and local conditions in sensitive energy systems was presented. With either limited transmission capacity or none at all, the SMILE islands present the importance of local energy resource integration.

Taking it a step further – as an important step from energy system analysis to energy market design – research on 100% RE share for one of the demonstration islands was conducted. A corresponding article with the title *"Technical Approaches and Institutional Alignment to 100% Renewable Energy System Transition of Madeira Island – Electrification, smart energy, and the required flexible market conditions"* [10] was published in *Energies* (vol. 13) in August 2020. With SMILE technologies, such as power-to-heat and power-to-transport, as well as additional RE capacity, a 100% RE share was achieved in a long-term model of Madeira Island energy system. However, its implementation shows to require energy market design structures to support this transition, especially for islands. This is elaborated in the following sections as a baseline for this report, which is further expanded by support mechanisms afterwards.

2.2 Energy market design approach

As presented in the previous work – both in the deliverables and the related research articles – islands have a larger need for self-sufficiency than well-embedded energy systems. Especially the production of fluctuating RE, such as wind and solar energy, is difficult to match with the demand. The same applies to the SMILE demonstration islands.

SMILE demonstrates options that address this problem through demand response, smart technologies and integration of electricity in other sectors. However, these technical and non-technical possibilities need to be implemented correctly to allow for balance and flexibility. This benefits not only the consumers, but also the energy providers, and allows the future modelled energy system to become reality. Hence, alignment with the energy market and potentially new energy market design structures are required. [10]

Defining the energy market aspect is one of the first required steps. The energy market consists, on the one hand, of the energy technologies and, on the other the hand, the energy itself that can define the market. The following definition is applied in this report and describes the applied energy market analysis.

"Markets are usually defined as a variation over the theme 'physical or virtual arena for the exchange of goods and services' and with particular reference to the energy sector, two types of markets are of relevance: markets for the exchange of technologies and markets for the exchange of energy or power.

Thus, market analyses can address whether potential buyers in a given area have a ready access to, e.g. heat pumps or electric vehicles or vice versa whether heat pump and electric vehicle suppliers are met by willing buyers. Market analyses can also focus on how energy, e.g. electricity, biomass and electrofuels are traded with a view to ensuring a functional market that can help exploiting the flexibility options in the energy system with a view to integrating fluctuating RE sources. The main understanding applied in this paper is the latter – i.e. the trading schemes for power and/or energy, which improve the operation of the energy system. The trade of technologies is, however, a prerequisite to this and therefore touched upon as well. Furthermore, the market can be viewed from either the supplier or the consumer side, where the latter is evaluated [in [9]] by analysing how the market should be designed from an end-user point of view." [10]

In a consequential step, local barriers and potentials are evaluated to find required changes in the existing energy market, which would improve the impact of the technological solutions. While this is primarily done for the SMILE islands individually, the changes and recommendations are aspired to transcend the individuality. The following structure is applied to this:

1) Identify technical scenarios with high RE share, including data on benefits
2) Identify the market context and show the existing barriers for the scenarios
3) Create transcendent recommendations or design proposals to overcome barriers

While 1) has been completed mainly through D8.2 and 2) has also preliminary been addressed in both D8.1 and D8.2, this report continues from there. In Chapter 3, the technical high-RE scenarios are recapitulated with a focus on the benefits, but even more so on the barriers in the current institutional contexts. After the SMILE islands' input, 3) is presented through recommendations relevant for all, based on research done accordingly and taking island input into account. The support mechanisms in Chapter 4 presents transcendent further recommendations for energy transitions on islands.

2.2.1 Review EnergyPLAN analyses

As presented in D8.1, EnergyPLAN *"simulates the mix of technologies in the whole energy system by identifying and exploiting synergies across the sectors"* [3]. This is done in the theoretically best way, where certain local limitations and technical restrictions are disregarded, as it simulates optimal system operation. The following aspects of modelling are therefore also of relevance for the market analysis, since the technical operation and recommendations influence the market ones.

Assumptions in EnergyPLAN to consider when identifying the market context and the barriers:

- Exploitation of synergies across all sectors (high connectivity)
- Technically optimal simulation (not market economically). The technical optimisation sets the upper boundary for how efficient the system can operate, integrate RE and minimise overall system costs, where market economic simulations also factor in how dispatchable units can operate on an external electricity market characterised by known electricity prices
- Technologies available and operational; no downtime or maintenance
- Fluctuating RE production is given priority over dispatchable power plants and/or import
- Flexible demands are following fluctuating RE production (in relation to capacities)
    - Heat pumps and TES
    - Electric Vehicles (to a certain share), V2G
    - Pumps in hydro power stations
    - Electrolyser and hydrogen production
    - BESS charge and discharge

In line with the market definition above, the exchange of energy is addressed in this deliverable, but for that to be relevant, the technology market has to be available. Hence, it must be taken into account, which technologies are assumed working in each model and under what conditions. The specifics for each SMILE island are presented in D8.1 and D8.2, and recapitulated in Chapter 3.

Technological assumptions to identify context and recommendations:

- Availability of technologies: RE capacity, heat pumps, TES, EVs, BESS, electrolyser, etc.
- Optimal set-up and integration of technologies in respective locations: households, public and private spaces, businesses and energy system infrastructure (e.g. district heating network, pumped hydro power stations, EV charging, etc.)
- Optimal operation of technologies (no technical limitations/restrictions and with certain flexibility, 'smart' operation)

Both the modelling and technological assumptions influence the outcome of the scenarios and shape the identification of the market context, the barriers and recommendations to overcome those, as presented in Chapter 3.

2.2.2 Next steps for energy market structure and support mechanism design

The discussion of the EnergyPLAN analyses and the consequential evaluation of barriers results in recommendations and design proposals for the energy market structures in Chapter 3. These are further evaluated with the purpose to scope the possibility for the introduction of a support mechanism for the promotion of the deployment of RE isolated system in the islands. Chapter 4 therefore addresses the mechanisms needed for the energy transitions on islands from a different point of view, presenting existing (environment-related) mechanisms, support needs recommendations to address those.

In detail, Chapter 3 presents the current energy market structures on Samsø, Orkney and Madeira, followed by the resulting market recommendations in Section 3.2. Chapter 4 follows up on those recommendations with the presentation and discussion of support mechanisms, addressing the investments, market alignments and restructuring needed to realize the technical energy system scenarios for the demonstration islands, as well as beyond. Chapter 4 therefore introduces aspects not only relevant for SMILE, but for all 2,400 EU islands, through the related H2020 EU funded NESOI project [11].

While D8.5 is written in parallel with this report on D8.4, it follows the discussion of energy system implementation by adding policy design recommendations to the technical and market analysis. In line with the policy analysis, a questionnaire is made in collaboration with SMILE project partners. While this presents the methodology of D8.5, some aspects relevant for the market analysis from the questionnaire are also transferred to this report D8.4 and can be found in Section 3.2. More information on the approach can be found in D8.5.

Finally, Task and Deliverable 8.5 will thereby conclude WP8 and the impact analyses through establishment of policy strategies to support the transition to high-RE systems in the three pilot islands, as well as a complimentary framework in EU islands.

3 Energy market structures to support the transition to high-RE systems

This chapter investigates how the transition may be supported or limited by present energy market structures and establishes recommendations for potential changes that better support the transitions to higher RE. In the first step, input from all demonstration islands is presented and discussed, and in the second step, recommendations are sought that transcends the different circumstances given by the three pilot project islands.

In general, the full transformation into 100% RE-based system includes a complex comparison of various technologies requiring balance, sector integration, and optimized utilization of resources [6]. Furthermore, for islands, this is characterized by increased need and/or possibility for self-sufficiency, as D8.2 concludes with a possible RE/self-sufficiency share of 85%, 38% and 31% by 2030 for Samsø, Orkney and Madeira Island respectively with the remainders being imported fossil fuels.

However, as these shares are the result of the optimized EnergyPLAN models, this entails a better integration of local resources, technologies and demands in reality and through institutional alignment. With increased electricity demand in the heating and transport sector, additional RE capacity is required, but also optimal local utilization. While the SMILE solutions address this to some extent, the essential energy market alignment with the energy system models is discussed here.

3.1 Energy market structures and barriers on the three SMILE islands

Based on the technical scenarios identified and the demonstrations projects ongoing on each SMILE island, this section aims at identification of institutional context and barriers for their implementation and further development. The requirement for energy market redesign is pointed out by showing the potentials and weaknesses of the current situations on the three islands in the following before addressing transcending recommendations in Section 3.2.

3.1.1 Input from Samsø (Denmark)

The SMILE demonstration on Samsø [12] entails local electricity generation from PV, storage in a BESS and consumers located at the Ballen marina. The BESS is to be charged and discharged in a smart way, according to demand and weather projections, aiming at high self-sufficiency for the marina. The consumers include boats and marina facilities, such as service rooms including sauna, an office and heat pumps. The boats are using the electricity for various on-board purposes, some of which may be flexible, e.g. heating and charging, but some demands are not flexible, e.g. lighting and cooking.

Samsø furthermore has a large capacity of wind turbines with an annual production exceeding the island's electricity demand by far. Additional EVs and power-to-heat technologies, such as heat pumps at both private and district heating level is suggested. While the first is suggested to include V2G, the latter is best added in combination with TES to allow flexible heat production according to the availability of excess RE production. To allow for even more flexibility, a biogas plant is considered to produce local fuel suitable for transport and long-term storage at reasonable cost (compared to BESS). The biomass currently used at the district heating plant is used for that, while power-to-heat and TES would supply the heat demands in the future/scenarios. Despite this inter-sector relation, no market set-up exists to coordinate and regulate this yet, though possibilities to develop energy communities that would manage both has been outlined in the SMILE report D7.2 [13].

As presented in the EnergyPLAN review (cf. section 2.2.1), various assumptions are made with the results relying on those. These can become barriers if not supported, as presented in the following.

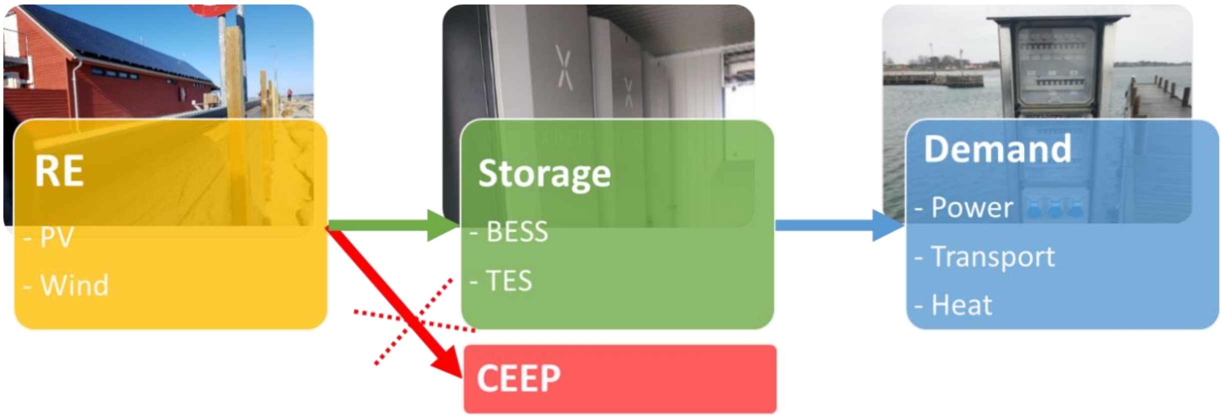

Figure 2: Energy market structure and the SMILE demonstration on Samsø: PV, BESS and boat sockets in Ballen marina (images from Ballen)

At the one end of the system, RE production is fluctuating and thereby often not matching demands, unless these are flexible or a storage option exists. Therefore, excess electricity production (EEP) from RE must be curtailed or can be sold at a low price off the island if the transmission capacity allows this. While no critical EEP (CEEP; EEP above the transmission line capacity) happens yet on Samsø as long as the transmission option suffices, it also does not encourage further investment and involvement into RE, which is required in the long run.

Storage options, however, can address this through direct electricity storage through BESS. Rather than using electricity storage to deal with EEP, electricity can also be directly used for various other end purposes including heat production. Since heating demands are not necessarily aligned with the RE production, conversion to heat and storage in a TES provides a beneficial low-cost addition to the system. To encourage this alignment of storage, conversion and consumption across sectors, new energy market structures and price incentives are required that align the demands (with or without storage) better with the production. In turn, this allows for higher RE production for the transition to a 100% RE share. Since 2019, an EU framework provides the bases for a legal framework with regards to energy storage including conversion, making use of potential access to relevant electricity markets (wholesale, balancing, etc.) [13].

As discussed, the EnergyPLAN scenarios of D8.2 indicate a large potential in converting local RE-based electricity generation to heat and storing it in a TES, when it is produced excessively, similar to potential hydrogen or biogas production, since the storage of these energies can be more economic than BESS. While EnergyPLAN models this in the most efficient way from a technical simulation viewpoint, also the market perspective needs to result in the same technological operation, where electricity is better to use when it is locally and sustainably produced.

D8.2 presents the energy system of Samsø with a RE share of 85% by allowing a large share of EVs to be charged flexibly, as well as including TES capacities available for flexible heat pump operation. When insufficient energy is available, EnergyPLAN allows through V2G further integration of the EVs in the island's smart energy system. The right energy market conditions need to support this.

While the Ballen marina is able to sell the locally produced electricity to the consumers at their own terms (currently 2.5 DKK/kWh (0.33 €/kWh)), the Danish hourly spot price is used for the optimisation of the local BESS. However, the average EV/heat pump owner has their own tariff agreement with an electricity distributer, which is usually fixed. District heating plants may also get tariff agreements, which relate to the national spot price, but not specific to the (RE) conditions on the island.

Denmark has experience with community ownership of wind turbines, which benefits the local community and increases acceptance towards the technologies. Involving the consumers in flexible demand side management through price incentives can further support the transition. Also, the consumers are the ones owning the EVs/boats, heat pumps (either household sizes or large-scale ones at community-owned district heating plants) and corresponding storages. By adjusting the market to support the rollout of those, the transition to RE can be further supported.

General recommendations resulting from Samsø conditions and experience follow in Section 3.2, after Orkney and Madeira input is presented and similarities and differences highlighted.

3.1.2 Input from Orkney (Scotland/UK)

For Orkney, the SMILE demonstrations address the local wind production/CEEP with smart heating options, hydrogen production and EVs [14]. Each of the solutions is aiming at smart operation, which would best integrate the local production and supply demands in heating and transport through electricity. The heating options include heat pumps and TES with phase-change material (PCM), partly in combination with BESS. Even though hydrogen is not further analysed in the SMILE context of Orkney, current hydrogen production is taking place in two locations in Orkney and supplies heat, fuel and power to the energy system. Finally, the number of EVs is both to grow, as well as to be charged, and potentially discharged, in a smart way.

The roll-out of EVs and potentially further electric heating alternatives requires additional RE capacity, which needs to be expanded while competing with energy produced from the existing power station or delivered through the transmission grid from the mainland. With a large fleet of either private or communal EVs, additional balance can be achieved through V2G. While many power-to-heat installations already exist, this is recommended to be expanded to make further use of local RE and address fuel poverty that way. To add another balance option to this sensitive energy system, district heating is suggested to be installed in the largest towns of Kirkwall and potentially also Stromness. This is to use large heat pumps as well as sufficient TES to use local RE when it is available. Further discussion of this can be found in a related article [8]. The EnergyPLAN scenarios suggest the conversion/storage in corresponding technologies when technologically suitable, which might not be encouraged at the current energy/electricity market structures of fixed end-user electricity prices.

While the purchase of EVs and efficient technologies is recommended, potential incentives need to be introduced to reach the high RE shares and levels of self-sufficiency. For example, as some of the demonstration technologies are supplementary/secondary heating installations, which on the one hand gives great flexibility, it is on the other hand unlikely that the private consumer would have access to and/or financial means or incentives for two installations.

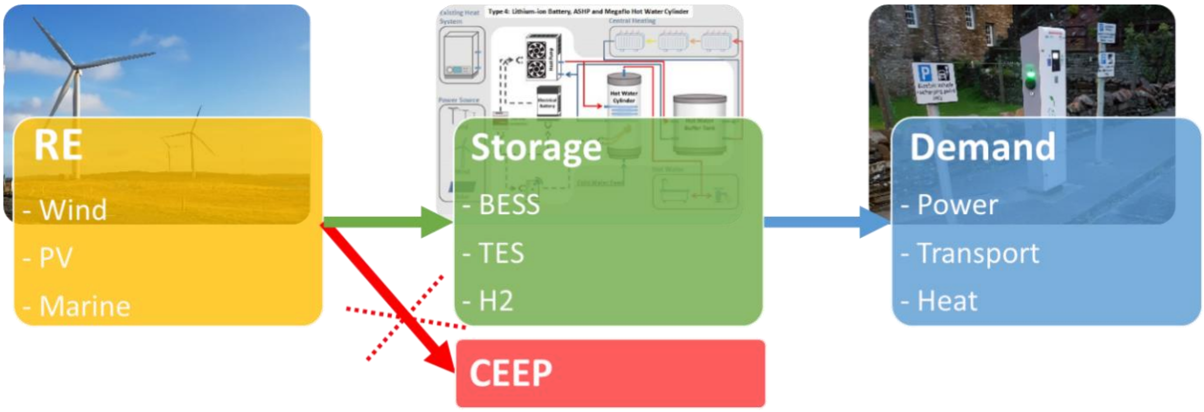

Figure 3: Energy market structure and the SMILE demonstration on Orkney: Wind turbines, SMILE pilot 'type 4' installation schema and EV sockets (images from Orkney, [14]**)**

The RE produced on Orkney is mainly coming from wind and partly from PV and local marine energy installations, such as tidal and wave power test sites, though also partly or soon in commercial operation. Characterised by some predictability, all these RE are fluctuating and requires some sort of storage to avoid critical excess electricity generation (CEEP; curtailment and/or low selling prices) to allow for effective supply of the local demands. Also, the inter-island limitations and bottlenecks are specific to Orkney, which encompass both transport of fuels and products as well as electricity. A market addressing this issue could hence solve two problems at once. A current solution in place on Orkney is the Active Network Management (ANM) service, which coordinated and balances the RE production with the demand to some extent. Though the ANM might not be considered a market, it influences the inter-island grid exchanges and can be used as basis to build an electricity market in the near future.

While the scenario work results in a 38% share of RE/self-sufficiency, this requires the technologies to be available and operate optimally and in relation to the RE production. For example, many EV chargers exist, but these are not smartly operated according to the local grid situation, as D8.2 suggests. The addition of the smart V2G option in the 2030 model reduces the import of electricity by 50%. In addition, the electrolyser is modelled to be smart, meaning it only runs when the electricity comes from RE technology, encouraging further RE capacity. Otherwise, the electrolyser would produce 'black/grey hydrogen' instead of 'green hydrogen' when running without sufficient RE available. The district heating suggestion relies on large heat pumps, operating according to local RE production and sufficient storage.

Overall, the "smartness" of the technological advances can be best supported by energy market structures that encourage flexible and dynamic consumption and/or production. The inter-island bottlenecks would also benefit from local electricity consumption according to the local production. While the Kirkwall power station on Orkney is still used for back-up and recent issues with the transmission cable, the dependence on it could be further reduced with better local market conditions.

Orkney's experience with using signals during the pre-/partial curtailment phase already initiates local consumption of the otherwise unused electricity by turning on heating units close to the potentially curtailed turbine, allowing it to keep running and producing revenue for the local community. However, this operation is limited to a specific zone within the Orkney grid and its corresponding wind turbine(s). While this shows potential, a full alignment of all zones and RE capacity would benefit the grid island-wide. [14]

As presented in D8.2, to reach Phase 3 in the transition to higher RE shares requires additional technologies and alignments. Like Samsø, Orkney's energy market does however not encourage further RE investments and still requires further sector integrating technologies for the transition in the long run. Recommendations based on this follow in section 3.2.

3.1.3 Input from Madeira (Portugal)

Madeira's energy system is completely autonomous and thereby differs largely from Samsø and Orkney, but similar trends can be observed. The SMILE demonstration on Madeira island includes BESS in combination with PV systems, both small and larger setups, as well as smartening of EVs of both business and commercial vehicles [15]. On the one hand, PV installations are currently either fully injecting to the local grid (no self-consumption) or not at all (only self-consumption), making further expansion of capacity problematic and the transition to higher RE shares difficult. EVs, on the other hand, are still very limited to some private users and tourism services on Madeira Island.

Due to the insularity of the energy system, expansion of RE capacity and integration is more complicated than on the other islands, and local optimisation and self-sufficiency even more important. Increased self-consumption is especially aimed for in the PV demonstration through household-size BESS, as well as local grid optimisation through large-scale BESS. The transport sector is to increase its share of EVs in both private and service areas, which is to be done in a smart way to align with the grid requirements, e.g. with algorithms that evaluate the best time to charge and discharge. With a future large share of EVs, but also electrified heating, cooling and cooking, more RE capacity and balancing is needed for the transition phases towards a 100% RE share.

In the Madeira energy system models of report D8.2, the local PV (and wind) production is balanced through the options with pumped hydro and V2G after an extension of the EV fleet. Furthermore, heat pumps are to convert and store energy in TES when possible, hence, when the model deems it suitable. Flexible synthetic fuel production is added for the future model of Madeira to illustrate the options and possibilities to further integrate RE fluctuations and fuel alternatives to semi-flexible transport demands. With these smartly modelled technologies, CEEP/curtailment is avoided/limited and all demands are met sufficiently, reaching 31% self-sufficiency. While this is an improvement to the reference scenario of 2014 with 11% RE share, the dependence on supply from local power stations remains, as well as grid constrains across the island.

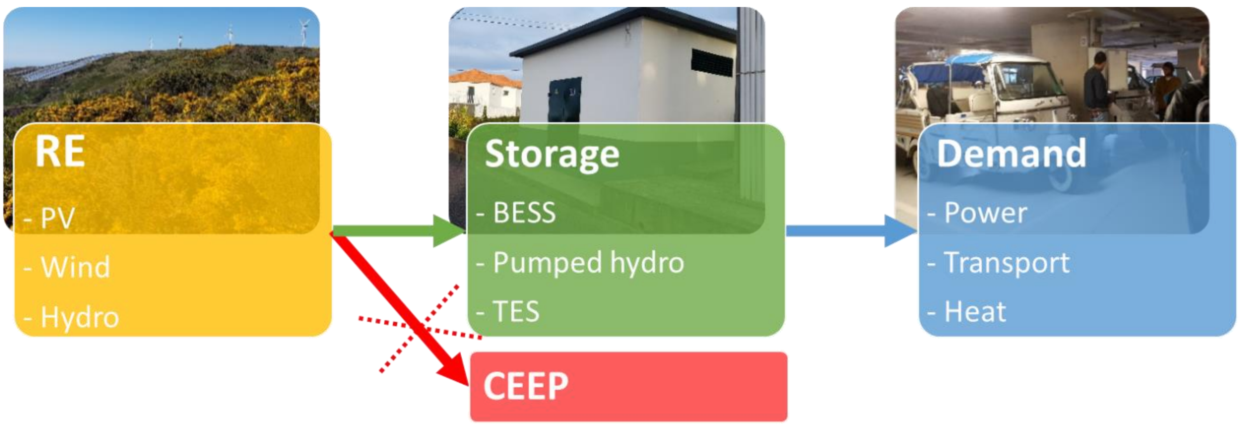

Figure 4: Energy market structure and the SMILE demonstration on Madeira: PV/wind power, *Fazendinha* BESS and Tukxi EVs (images from Madeira)

To realise the energy system presented in report D8.2, the assumptions presented in Section 2.2 apply, and need to be replicated through this energy market structure evaluation and design. This has been done in an elaborated study of Madeira island in [10], emphasising the need to align technological and market innovation. In contrast to many other islands, including Samsø and Orkney, Madeira has the advantage of being able to manage the transmission and distribution across the island through their local systems operator EEM (Empresa De Electricidade Da Madeira). While this limits the options to a certain extent, it allows EEM to operate according to local production and demand.

While SMILE addresses smartening of the grid through algorithms and BESS, Madeira Island also has various electricity tariffs designed to encourage consumers to use electricity during certain times, e.g. see Figure 5, with lower time-of-use tariffs in the night as this is when curtailment tends to happen [16]. However, while this addresses the current peak around noon and early evenings, it might not be suitable for high RE scenarios with increased electricity production from wind and sun as suggested in the long run. More specifically, the time-of-use tariffs might not include the fluctuations of wind and PV in a sufficiently dynamic way. Furthermore, the tariffs are the same, no matter which end use they supply: direct electricity, heating or transport demand.

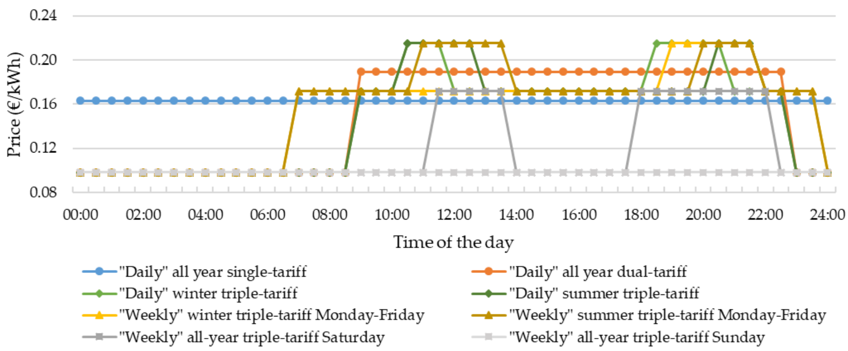

Figure 5: Time-of-use tariff options in Madeira [10]

Contrary to the current situation with generally higher curtailment during the night, the EnergyPLAN model from 2030 is indicating no curtailment due to the flexibility included in the simulation. This is reached through the potential for balance through flexible demands shifted to TES, V2G and synthetic fuel and needs to be enabled in reality through the right energy market structures.

The experience on Madeira shows, however, that daily tariffs (without the weekend incentive) are still preferred [16], and comfort and/or time constrains [17] have a bigger impact on the time-of-use than the price variations of up to 0.12 €/kWh. To align the suggested EnergyPLAN operation with the demand side, therefore, requires more elaborate solutions, which also address the required grid stability, by potentially including the end-users for balancing. These are discussed below in the aim for transcending recommendations for all islands.

3.2 Market recommendation transcending the SMILE islands

The following information can be gathered from the demonstration islands as well as from relevant and related research with the aim to find transcending recommendations for energy market structures to support high RE shares on (the demonstration) islands. It is based on the assumption that energy markets need to be re-designed to adjust the demand to the supply, rather than the other way around as it has been done before and as markets have been designed in the past. Hence, if the flexibility is not available on the supply side any longer due to its fluctuating nature, so it must be created on the demand side. In other words, the increasing share of intermittent production from RE requires intermittent demand. While the intermittency is often met with suggested increased levels of cross-border trading [18], this is limited on islands. Instead, the SMILE demonstrations show options of local utilisation and cross-sector integration, yet not flexible enough, especially in the transition to higher RE. As report D8.2 and the previous section showed, high levels of unused intermittent electricity are already an issue on all SMILE islands, which needs to be addressed as its importance will increase in the long-term.

Recently, consumers have been recognized as crucial, powerful parts of the future energy system, where TSO and DSO are not the only system operators, as the ‘system’ behind the consumers’ meter becomes increasingly important. Today, these possibilities of consumer engagement are growing to become more active and competitive, while the costs of balancing the system are assumed to increase due to a growing demand (though this is somewhat context specific). This leads to an increased value of flexibility, which hitherto is mostly unused, and could shape the structure of future energy markets. With distributed energy and more specifically electricity generation follows a new understanding of flexible consumers as distributed energy or electricity resources. [19]

As of now, the demonstration islands show various links to the national energy markets, as the responsibility normally resides centrally and far away from the islands, which in turn does not take into account the local limits and possibilities of each island. With production becoming more decentralised, the responsibility and capabilities should too, which would address the dependencies of the islands on imports, transmission lines and/or power plant productions. The SMILE islands have RE shares of 60%, 18% and 11% in the reference energy system of Samsø, Orkney and Madeira respectively and even continue having low cost exports, high cost imports and/or curtailment after the initial introduction of SMILE technologies. This points to a potential of strengthening the energy markets locally.

Overall, the intermittency can be addressed through the consumers and the smart technologies that address the demand side. By integrating these, flexible consumption can be commercialized through an adapted local energy market and to better fit with the decentralized production. The SMILE technologies are enabling the first step and the flexible market the second. This is also addressed in parallel work in SMILE WP7 and more specifically in report D7.4.

As pointed out in each of the islands, electricity prices do not encourage the consumption during hours of high RE share, but the ‘commercialisation of flexibility’ could aim this towards local RE. The more locality specific this can be done, the better internal bottlenecks and grid constrains can be overcome, as can be found on the demonstration islands. Incentivising flexible consumption through economic operation can further encourage the needed investments in required technologies. The 2019 electricity market directive further supports this in article 31 and 32 with, respectively, ‘Tasks of distribution system operators’ and ‘Incentives for the use of flexibility in distribution networks’ [20].

Based on the above-mentioned points, the following general points are recommended, to be further elaborated below:

1. Consumption needs to adapt to production, resulting in a flexible/dynamic demand side
2. Demand side improvements should benefit both consumer, grid operator and producer
3. Smart technologies (EV, Heat Pumps, etc.) create possibility for changes in consumer behaviour
4. Market needs to incentivise this change

As EnergyPLAN analyses and report D8.2 showed, the technologically optimal scenario is also to reflect the market economic optimal, which can be achieved by facilitating locally the integration of local RE production. While the algorithms can give control over certain flexible consumers in an aggregated way (Ballen marina, heat installs, or Tukxi charging), the remaining consumers are to be addressed differently. If algorithms are not available or suitable, the market can facilitate this through direct marketing and activating consumers to dynamic consumption.

The research carried out on Madeira Island [10] emphasises the importance of incentivising the operation of smart technologies, rather than the purchase [21]. Also, alignment with proximity, e.g. locational signals or prices, reduces transmission costs, which should be forwarded to the consumer to increase positive consumer reception [22], [23]. Direct marketing options address the flexibility and willingness of the consumer for this. This is similar to the different tariff options already available in some places, such as Madeira, but adding the intermittency aspect. These different perspectives are highlighted by the following.

"As evidenced [there], the consumer can be economically incentivized to use electricity at certain hours—in either the electrified scenario through heat pumps and EV charging or in the smart energy scenario through additional technologies. This can be done when it is also beneficial for the grid operator, resulting in a flexible and dynamic energy market, where the fluctuating RE production is in the centre. […This leads to the suggestion of] a potential price mechanism according to RE production, with the option to take the electricity demand (projection) into account. Similar average daily prices [can be applied], but with more extreme peaks, incentivizing dynamic consumption. […] taking into account the sustainability of the local RE production, the transmission and their costs, the price signals must be adjusted accordingly. […] Furthermore, the proximity of the consumer to the production side is to be taken into account to reflect the true transmission/distribution cost."

"Hence, the local TSO/DSO is to control and schedule price signals according to the technical capabilities of the overall energy system—similar to what is already done—but including further market perspectives by considering the consumer as a controllable load that requires incentives. This can be applied to EVs, heat pumps and other demands that allow flexible operation either through smart charging, TES or hydrogen storage capacity resulting from the first step. […] "When this is in place, a smart approach to V2G must follow to bring the full potential to the energy system by providing balance through short-term storage.[…] Thus, a selling price higher than the buying price is recommended, signalling the value to the market." – highlights from the institutional analysis of Madeira [10]

While consumers as end-users could be responsible for this themselves, they also have the option of aggregated control, such as is done with the SMILE project. This could delegate control to someone familiar with the real-time market, who could offer products and services to consumers.

Based on the above-mentioned points, the following is recommended:

1. Electricity prices should reflect RE share, proximity and avoided costs
2. Forecast and schedule price signals that are transparent and reflect true cost
3. Encouragement of dynamic "smart" consumption with available technologies
4. Value of V2G and BESS should reflect true cost

5. Consumers are responsible to follow price signal or use aggregated options

These recommendations could increase value and competitiveness of local RE productions where current conditions make RE technologies unfeasible in a further transition to higher RE shares [24]. Proper electricity market setups can further create the incentive for future investments [25]. These must be designed under consideration of transport and heating demands in a smart energy systems, including potential district heating and/or cooling in an island-wide economical evaluation [26].

Concluding Chapter 3, certain support mechanisms for the energy transition of islands are needed, which is further addressed and elaborated in detail in Chapter 4, concluding this report by matching islands' needs with available instruments in Section 4.4. Before however, the results from the questionnaire in report D8.5, which are relevant for the energy market design, as explained in Section 2.2, are outlined in the following. More information can be found in D8.5.

3.3 Market recommendations from questionnaire

In SMILE report D8.5, a questionnaire is presented to evaluate themes within energy system policies and planning requirements to implement the SMILE technologies and transition to higher RE shares. Since some of the themes overlap with the objective of D8.4, the following outlines the most relevant results from this questionnaire, while detailed information can be found in D8.5.

As identified in Chapter 2, there are two market aspects to consider: the technology and the energy market. Both themes are evaluated in terms of barriers and suggestion in collaboration with the SMILE islands. While some aspects overlap with the analysis and recommendations presented above, the following is supported by the questionnaire and collaboration with partners on Samsø, Orkney and Madeira.

In regards to the technology market, barriers include a lack of consumer education and awareness about optimal use of technologies, which hinders their implementation, as well as a financial barrier due to centrally/nationally operated grids and supply services. Recommendations include the raising of awareness and the purchase of 'smart' appliances, which would address the consumer barriers, as well as support of more local financing and operation, e.g. through specific local tariffs and promoting sustainable mobility, addressing the national/expensive current operation of technologies.

In regards to the energy market, where flows of electricity, thermal energy or gasses is included, barriers and recommendations vary across the SMILE islands as well as across the energy sectors. Generally, the opportunity for small-scale producers of energy are limited and/or heavily regulated, presenting a barrier to facilitate small and local energy supply and trade. While Madeira forms an exception with an autonomous market, the islands also present options for alternative business models and appropriate schemes according to local market demands. This can be further promoted and replicated in other regions, fostering a more active and local participation in the energy market.

4 Support Mechanisms for Energy Transition of Islands

This section focuses on the support mechanisms available for the energy transition of islands; the existing mechanisms are initially reviewed with a specific focus on environment-related ones, then the islands' needs are analysed and a gap analysis is carried out versus the available instruments with the elaboration of recommendations for bridging the gap between islands' needs and available support mechanisms. This chapter therefore elaborates the energy market structures and recommendations identified with and for the SMILE islands in Chapter 3, as well as takes a look beyond SMILE.

Besides the review and discussion of existing mechanisms and needs below, an overall support mechanism for islands to get money for funding of energy transition investments, including RE, transportation, infrastructure, etc. is the Just Transition Fund [27]. It is part of the just transition mechanism, itself part of the green deal, presented in the following.

4.1 Review of Existing Mechanisms

The implementation of energy transition projects like those of interest for the SMILE project specifically for islands can be supported through public or private funds.

Public sources to support the energy transition of islands include direct and indirect EU funds, national and regional funds, cash flows from International Financial Institutions (IFIs), National and International Development Banks, etc. Private funds include those coming from commercial banks, private corporations, investment funds and more novel those collected through crowdfunding platforms. Both categories of funding bodies are interested, for different reasons, in supporting the energy transition process, with the aim to reach carbon-neutrality objectives set at EU level for 2050 (mainly for public entities) and to meet mandatory and voluntary targets for Environmental, Social and Governance (ESG)-linked investments and also to meet minimum financial performance requirements to generate revenues for investors (mainly for private entities).

Private financial actors like commercial banks offer both equity and debt instruments in all EU Member States, although different players operate in different countries or regions (no significant difference seems to exist with reference to islands). They are generally more interested in supporting the implementation of project types already present in their portfolio, such as renewable energy production and energy efficiency actions.

Investment funds [28] are generally interested in large-scale investments, having a size of at least few million Euros, which may be a barrier for the financial support to small projects at building or community level. Another potential barrier is constituted by the required profitability, generally expressed as an Internal Return Rate (IRR) of at least 7-8%, which in some cases can be difficult to achieve in the absence of public support. This last barrier is specifically important for infrastructural projects.

Crowdfunding [29] may be an interesting solution for small and medium-sized energy projects and/or for those having a certain degree of innovation. Indeed, crowdfunding typically supports a mix of small projects and accepts a lower profitability (around 5%).

As concerns public funding, in addition to direct funds provided by the EU or national/regional authorities in the context of energy and climate plans, an interesting solution is constituted by platforms promoted at EU level and implemented through IFIs and commercial banks with the aim to de-risk energy related projects, thus reducing the cost of capital.

These funding opportunities briefly described above and schematized below are further analysed in the following paragraphs.

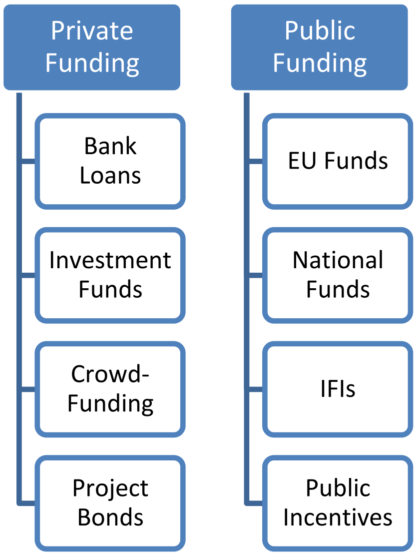

Figure 6: Scheme of Private and Public Funding Opportunities

4.1.1 Public Funding Opportunities

Public support to energy transition projects is very important with the final aim of meeting the ambitious national and EU-level targets for energy efficiency, energy production from renewables and mitigation/adaptation to climate change, especially in specific contexts – such as islands – where these issues are particularly relevant due to the specifics of the local ecosystem and energy system. The public sector may invest directly to support projects or indirectly to stimulate and mobilize private investments in areas such as strategic infrastructures, enabling technologies, early-stage projects or solutions that are perceived as high-risk by private investors. Public funds include those from the EU, its Member States and local authorities, but in most cases the main sources of finance come from EU funds (managed directly or indirectly by Member States or the European Investment Bank) and to national funds (direct or indirect, through regions or local banks).

As concerns EU funds, this covers all opportunities belonging to the EU Multi-annual Financial Framework, i.e. the EU budget prepared on a seven-year timeframe, with the last completed period being 2014-2020 and the next period being 2021-2027. Over 50% of the EU budget is distributed through five structural funds, i.e.: European Regional Development Fund (ERDF), European Social Fund (ESF), Cohesion Fund (CF), European Agricultural Fund for Rural Development (EAFRD), and the European Maritime and Fisheries Fund (EMFF). In addition, further programmes have been created as for instance the European Green Deal package, aiming at supporting the EU energy transition through grants, loans and provision of technical assistance. During the 2014-2020 period, the EU commitment was to allocate 20% of expenditure on climate actions, while in the 2021-2027 budget it is foreseen to set a more ambitious target, i.e. 25% of expenditure contributing to climate objectives.

As energy transition is also a priority topic for the individual EU Member States, they may also allocate part of the funds of the national budget to invest in this field, e.g. realizing directly projects related to public assets (buildings, energy infrastructures, public transports, etc.) or to foster private investments with incentives and grants on strategic topics (e.g., buildings retrofitting, energy efficiency actions, renewable energy sources, etc.). These national funds can, on the one hand, rely on funds from the EU budget or, on the other hand, be channelled through regions, municipalities or other local authorities.

Another important funding body is constituted by the category of IFIs and, although to a lesser extent, also by national development banks. The main actor in this category is constituted by the European Investment Bank (EIB), operating in all EU Member States, and for some areas also by the European Bank for Reconstruction and Development (EBRD, operating – among EU Member States – in Bulgaria, Croatia, Cyprus, Estonia, Greece, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia), the Black Sea Trade and Development Bank (BSTDB, operating among EU Member States in Bulgaria, Greece and Romania). These institutional banks typically provide direct funding only to large-scale projects (investments higher than 5 million Euro), or implement credit facilities through local partner banks (providing loans and guarantees) to support smaller projects. Among these institutions, two are worth being mentioned together with their most relevant credit facilities, i.e. the EIB with the Private Finance for Energy Efficiency (PF4EE) facility and the EBRD with the Green Economy Financing Facility (GEFF) initiative.

The EIB is an international financial institution having the EU Member States as shareholders and having invested in the last five years 12-14 billion Euro in the energy sector [30], [31]. The focus of EIB activities on energy is on four main areas: unlocking energy efficiency, decarbonising energy supply, supporting innovative technologies and new types of energy infrastructures, and securing the enabling infrastructures. The EIB promotes with the support of the European Commission, the PF4EE instrument [32], whose aims are to make energy efficiency lending a more sustainable activity within European financial institutions and to increase the availability of debt financing to eligible energy efficiency investments. PF4EE operates through a 480 million Euro long-term financing to local banks, plus 80 million Euro to cover a risk sharing facility and expert support services.
The PF4EE technical eligibility criteria vary according to the specific focus assigned in each Member State but typically are based on the investment belonging to a list of standard measures for low-CAPEX ones and on meeting specific criteria on percentage energy savings and Net Present Value (NPV) of the investment for medium- and high-CAPEX ones (up to 10 million Euro of project cost and 5 million Euro of covered loan).

On the other hand, the EBRD [33] is owned by 69 Countries, plus the EU and the EIB and operates to support the economic development in States in Central-Eastern Europe, Southern-Eastern Mediterranean, former CIS Countries and Central Asia. The energy sector is key in the bank's strategies, with EBRD supporting projects to improve energy efficiency, move towards a low-carbon energy sector, and contrast climate change. The EBRD directly acts on large projects (from 3 to 250 million Euro), whereas smaller initiatives can receive support through local commercial banks. An initiative worth being mentioned is GEFF constituted by the EBRD [34] and supporting companies and individuals wishing to invest in green technologies. Eligible projects include energy efficiency, production from renewable sources but also resource/water efficiency, circular economy and climate change mitigation and adaptation. The GEFF programme operates through more than 140 local financial institutions across 26 countries with almost 4 billion Euro of EBRD finance; over the last years, more than 130,000 clients were supported by the programme, globally avoiding almost 7 million tCO_2/y of GHG emissions. The eligibility criteria for GEFF slightly differ from an initiative to another, but typically they include a maximum investment of few million Euro, a minimum IRR of 10% for energy efficiency projects and 0% for renewable energy projects and an energy saving ratio of at least 15-20% compared to the baseline situation for energy efficiency projects.

To conclude, two funding sources involving national and local authorities are worth being mentioned: Public-Private Partnerships and public incentives to support private investments in the energy field

[35]. Public-Private Partnerships are constituted to create a cooperation between a private actor and a public institution aimed at jointly realizing projects on public infrastructures or assets of public interest. Typically, this implies the creation of a Special Purpose Vehicle (SPV) [36], with shares partly owned by the private company and partly from the public body and investment for project implementation divided among shareholders when needed, with the potential support of external financing sources. This kind of partnerships are typically characterized by long-term agreements, which also make feasible projects with relatively low-return and long payback .

As concerns public incentives, they are usually implemented in different ways in EU Member States. For instance, there are mechanisms that reward the operation rather than the simple implementation of projects, like feed-in tariffs for renewable energy projects, which are paid by national authorities per unit of electricity produced, or white certificates for energy efficiency projects, which are released per unit of saved energy. Another mechanism supporting the realization of projects is based on tax deductions, which allows subtracting from taxes a part of the expenses for an energy efficiency or renewable energy project. This applies both to individuals and legal persons and is of particular interest in Member States characterized by high tax rates. The tax deduction can typically be applied over a time-span of 5-10 years but in some cases it is also possible to transfer the credit to a bank or even to the contractor that realizes the works.

4.1.2 Private Funding Opportunities

Loans are the most common financial product offered from private commercial banks to support several types of projects; indeed, they are applicable to projects of any scale and to any client, depending on the evaluation of financial solvency of the borrower (for corporate loans) or on the financial performance of the project (for project-related loans). The share of funds provided by banks through loans can typically reach only a maximum of 60-70% of the total investment, depending on the nature of the project and on the type and amount of collateral provided by the promoter). The remaining part of the investment shall be covered by an equity component to be provided by the promoter through own funds or other sources of funding including public ones. Specific credit facilities or financial products may be available for the support to energy-related investments, although these are generally related to the presence of public incentives (e.g., tax credit transfer) or to a long-term financing by an international financial institution (e.g., EIB PF4EE facility and EBRD GEFF, implemented through local commercial banks).

Another potential source of private finance is constituted by investment funds, which collect funds from individuals and corporate investors and invest them into medium/long-term risk capital of companies with expected high growth potential, with the ultimate aim of generating revenues for investors. The timeframe of projects of interest for investment funds is of at least five years and may be even longer for “patient capitals” such as those from pension funds. Some investment funds specialized in energy-related projects are present on the market, which differently from commercial banks may also own a technical experience in the energy sector and the consequent ability to evaluate the risks related to project implementation.

As mentioned above, crowdfunding is a funding scheme relying on capital collected from a large number of private investors (mainly individuals, but also corporate ones) through an online platform. In case of equity crowdfunding, reward of investors is related to dividends generated by the company (or project) receiving support, whereas for loan crowdfunding, investors are rewarded with an agreed interest rate. This solution is especially interesting for small- and medium-sized projects, such as for the creation of energy communities (i.e., group of citizens and small businesses acting jointly to self-produce energy from renewables).

Another potential opportunity is constituted by project bonds (also named "green bonds" [37], when the focus of the investment is a sustainability project), which are financial instruments aiming at collecting funds from individuals and corporate investors through the emission of bonds linked to the implementation of a specific project. These bonds can be issued by private corporates or by Special Purpose Vehicles created among private companies or within Private-Public Partnerships. These bonds have a fixed duration and a periodic coupon at a fixed interest rate, thus constituting an interesting funding source for companies as an alternative or integration to conventional bank credit, especially for medium/long-term investments or refinancing of existing projects.

4.1.3 Commercial Banks Projects and Corporate Financing

As mentioned above, the financial support to energy transition projects may be provided by commercial banks through two different approaches, i.e. the corporate finance and the project finance approach. In the Corporate Finance Model, the financing partners (e.g., banks with dedicated loans, public bodies with grants, project promoters with equity) provide funding to the promoter (e.g., a company, group of companies or public institution) considering only the financial strength of the project promoter itself. For this reason, the promoter is responsible for the repayment of the loan without direct reference to the financial performance of the project and therefore the credit risks borne by the financing partners are related to the potential default of the promoter and not of the project. Figure 7 presents the corporate finance concept scheme.

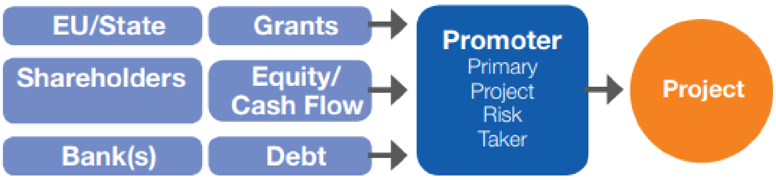

Figure 7: Corporate Finance Concept Scheme [38]

In the corporate finance scheme:

- the bankability of a project depends on the creditworthiness of the project promoter, which typically is the borrower;
- the creditworthiness depends on the solvency of the borrower, i.e. the capacity to repay the debt, including capital and interests;
- this capacity to repay the debt is assessed analyzing the company's profitability, balance sheet, cash flows;
- in case provided that the company is evaluated as reliable and creditworthy, this approach does not foresee any analysis on the specific project, related to its nature, technical feasibility and economic profitability, since the debt is completely dissociated from the project risk.

For projects related to energy transition of islands, this corresponds for instance to the case of the local DSO (or local utility managing the electricity system, or DH network, or water supply, etc.) deciding to implement an energy transition project on own assets and, being a large and financially strong company, it receives financing from commercial banks independently from the specific technical nature of the project.

Since the evaluation of company creditworthiness is not under the scopes of this report and no technical aspect related to the energy transition project can influence bankability according to this approach, it will not be further discussed in the following sections.

On the other hand, in the Project Finance Model the project is implemented and financed through a SPV, which is a legally and financially standalone project company having the project proponents as main shareholders. Therefore, the SPV receives equity from the project proponents, grants from the involved public bodies (if any) and loans from banks, with no consequent recourse to the project promoters. [38]

This kind of approach has the main purpose of receiving equity, as well as a significant share of debt capital, which is accounted on the SPV balance sheets and not on that of the project proponents. Hence, this approach constitutes an off-balance-financing for project promoters. It is clear that only cash flows related to the project should be considered to assess the ability to cover debt service and returns on equity; for this reason, banks and lenders usually analyse debt services, loan life and project life coverage ratios to evaluate the capacity of the project to repay loans.

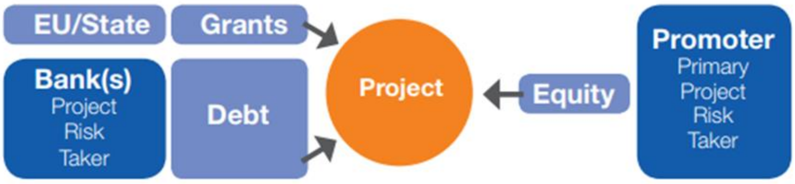

Figure 8: Project Finance Concept Scheme [38]

In the project finance scheme:

- the bankability evaluation focuses on the specific project, which is isolated from a legal and financial perspective in a SPV, with limited recourse to the project promoters;
- the project bankability depends on:
    - the capacity of the SPV to generate sufficient and stable cash flows to repay the debt (capital and interests),
    - the proportion of equity guaranteed by project promoters,
    - the value of project assets and/or of other collateral,
    - other structural aspects and risks specifically related to the project, including legal, environmental and social topics.

For projects related to energy transition of islands, this is the typical approach for projects implemented by the local utility in cooperation with third companies or local authorities through private-public partnerships.

Regarding the view of institutional and commercial banks, an important source of information is constituted by the stakeholder consultation carried out in by RINA in the ReUseHeat project [38], focusing on low-temperature district heating but whose results can be extrapolated to energy transition projects, too.

Based on this input as well as on a literature review, the main conclusions regarding bankability, from the commercial bank perspective are presented in the following bullet points:

- commercial banks prefer corporate finance compared to project finance since the risks related to the company operation and performance are easier to evaluate and manage compared to those related to a single project especially if not based on a very mature technical solution. On the contrary, banks operating with institutional credit lines need to adopt a project finance approach since eligibility criteria are typically related to the technical and financial performance of single projects;

- in case support of public bodies is provided, like in the case of Risk Sharing Facilities from national/supranational entities or in case of guarantees issued from municipalities for infrastructural projects, banks may accept a slightly higher degree of risk for projects. No significant priority is given by banks to projects supported by public incentives on operation, since they prefer that cash flows to repay the loan are sufficiently available from the project and not rely on benefits that may change according to the political context;
- similarly, banks adopting a CSR (corporate social responsibility) strategy strongly oriented on environmental topics or willing to complete a sustainable portfolio of projects may devote a specific amount of funds on energy efficiency or GHG reduction or circular economy projects and therefore may accept a slightly lower financial return for these kinds of projects; on the contrary, the majority of banks stated that environmental benefits are only a nice-to-have that do not play a key role in case the project does not guarantee a minimum level of economic profitability;
- different opinions exist among banks regarding the opportunity of financing public-private partnerships. In some cases the presence of a public body among the project proponents is considered as a guarantee, whereas in other cases banks clearly state that they prefer to finance private companies since the solvency of municipalities in some countries is worse and generally more difficult to evaluate;
- banks agree on the fact that maximum time horizon for projects is around 15-20 years for infrastructural projects and around 5-10 years for other projects including renewables/energy efficiency-related ones. The loan duration is typically shorter compared to these technical lifetimes and in some cases even shorter than the expected payback period for the investment, in order to get the loan repaid before the equity of the project proponents;
- regarding the financial eligibility criteria for these investments, only few banks provide quantitative data, since these values strongly depend on the client creditworthiness; however, a part of the interviewed banks mentioned a maximum payback of 10 years and a minimum internal rate of return (IRR) of 8%. Furthermore, they agreed that in order to have sufficient cash flows to repay the loan, an average debt service coverage ratio (ADSCR) higher than 1 is definitely required, with most interesting projects having ADSCR higher than 1.3-1.4;
- technical risks are carefully considered by banks in project finance approach; the maturity of the adopted technologies is considered, both in terms of single components and of overall technical solution (source+technology+user), but generally, it is not worth paying a third party to carry out a technical due diligence for loans below 10-15 million €, thus it is important that project proponents provide extensive details on the technical solution, the possible risks and the measures to avoid them or mitigate their effects, the evaluation of their impact on the business plan, etc.;
- an opportunity different from traditional loans between the bank and the project proponent is constituted by green bonds, which can be issued by banks to cover funding of a group of projects of the same category (one of which could be, investments in energy transition of islands), thus minimizing the risks for third parties to invest in a single project.

4.2 Review of Existing Environment-Related Mechanisms

The present section focuses on support mechanisms that could apply to energy transition of islands and are particularly focused on environmental aspects, including but not limited to the mitigation and adaptation to climate change.

4.2.1 Equator Principles

The Equator Principles (EPs) is a risk management framework, adopted by financial institutions, for identifying, evaluating and managing environmental and social risk in projects. They constitute a minimum standard content for due diligence and monitoring of projects aimed at supporting decision-making.

The EPs have worldwide application and extension to all industry sectors whereas regarding the type of financial products their application is limited to Project Finance Advisory Services and Project Finance with CAPEX higher than 10 million USD, Project-Related Corporate Loans with CAPEX higher than 100 million USD and Bridge Loans. Currently the EPs have been adopted by 116 Financial Institutions (EPFIs) in 37 countries, which cover most of international project finance debt in developed and emerging markets [39], [40].

EPFIs commit to the implementation of the Principles in their internal environmental and social policies, procedures and standards for financing projects and commit not to provide Project Finance or Project-Related Corporate Loans to projects that do not comply with the Principles.

The EPs have promoted convergence around common environmental and social standards, and also multilateral development banks such as the EBRD and export credit agencies through the OECD Common Approaches are increasingly relying on the same standards as the Principles. In order to increasingly account for climate-related aspects in the realization of new projects, the EPs IV [40] published on July 2020 introduced the requirement to carry out a Climate Change Risk Assessment aligned with Climate Physical Risk and Climate Transition Risk categories as outlined in the Recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) [41]. Specifically, the EPs state that a Climate Change Risk Assessment is required:

- for all Category A (Projects with potential significant adverse environmental and social risks) and - as appropriate - Category B Projects (Projects with potential limited adverse environmental and social risks), to cover physical risks;
- for all Projects having combined Scope 1 and Scope 2 emissions greater than 100,000 tCO_2e/y, to cover climate transition risks and carry out a Climate Change Alternatives Analysis (which evaluates lower GHG alternatives).

4.2.2 EU Sustainable Finance

The European Commission has set up a Technical Expert Group (TEG) on sustainable finance with the aim of developing, in line with the EC legislative proposals of May 2018, the following items:

- an EU classification system, i.e. “EU taxonomy” [42], to determine whether an economic activity is environmentally sustainable. The final report, published in March 2020, includes guidance on how companies and financial institutions can make disclosures using it, and is supplemented by a technical annex containing technical screening criteria for 70 climate change mitigation and 68 climate change adaptation activities, including criteria for ‘do no significant harm’ (DNSH) to other environmental objectives and an updated methodology section to support the recommendations on the technical screening criteria. In addition, the TEG has prepared Excel-based tools to help with the implementation of the Taxonomy.
- an EU Green Bond Standard (EU GBS); the final report, published in March 2020, proposes a voluntary standard offered to issuers, verifiers and investors of green bonds who wish to align with market best practices (e.g.: Green Bond Principles (GBP) developed by the International Capital Market Association (ICMA)). The intent of GBS is to regulate the four core components of Green Bonds: Green Projects, Green Bond Framework, Reporting, and Verification. It can be

used to finance projects in the EU as well as outside the EU, and it can be used for any type of listed or unlisted bond or capital market debt instrument by any public or private issuer. Proceeds from EU Green Bonds should finance "Green Projects" defined as those projects that are aligned with the requirements as set out in the EU Taxonomy.

- methodologies for EU climate benchmarks and disclosures for benchmarks; the final report, published in September 2019, i.e. the Benchmark Regulation and the delegated act, introduce a common framework to ensure the accuracy and integrity of benchmarks referenced in financial instruments, financial contracts, or investment funds in EU and the delegated acts provide an explanation of how Environmental, Social and Governance (ESG) [41] factors are reflected in each provided and published benchmark, minimum content of the explanation on how ESG factors are reflected in the benchmark methodology, and minimum standards for EU Climate Transition Benchmarks and Paris-aligned Benchmarks;
- guidance to improve corporate disclosure of climate-related information; the final report, published in January 2019, 'Report on Climate-related Disclosures', intends to assist companies in developing high quality climate-related disclosures that comply with the Non-Financial Reporting Directive (NFRD) and address the recommendations of the TCFD.

It is also specified that green bonds are expected to play a major role in the provision of support to energy transition projects; indeed, they help bridging the gap between providers of capital and green assets, supporting local authorities or project promoters in raising finance for projects to meet climate objectives and enabling investors to achieve sustainability targets. In the specific case of projects for energy transition of islands, the most relevant benefit is that to allow access to long-term capital. For this reason, the EU Green Bonds Standard has a paramount importance since it constitutes a clear guidance for institutional investors, pension funds and sovereignty wealth funds on sustainability aspects of their investments as well as to strategic issuers including local and regional public authorities.

4.2.3 Financial Support Mechanisms for Sustainable Energy

Regarding the potential credit lines for sustainable energy, three main existing support instruments from multinational development banks were analysed: the Private Finance for Energy Efficiency (PF4EE), the ELENA facility, promoted by the EIB with the support of the European Commission, and the GEFF, promoted by the EBRD with contributions of many different international donors. [38]

The PF4EE is a financial instrument developed based on a joint agreement between the EIB and the EC, whose aims are to support energy efficiency investments through the improvement of access to adequate and affordable sources of commercial funding. The PF4EE mainly supports projects that comply with National Energy Efficiency Action Plans or other energy efficiency programmes of EU Member States.

According to PF4EE official documents, the credit facility has two core objectives:

- to make energy efficiency lending a more sustainable activity within European financial institutions, considering the energy efficiency sector as a distinct market segment;
- to increase the availability of debt financing to eligible energy efficiency investments.

In addition to the 480 million Euro of long-term financing from EIB, the EC supports PF4EE through LIFE, its programme for the Environment and Climate Action; specifically, the LIFE Programme committed 80 million € to finance the credit risk protection and expert support services. Therefore, the PF4EE instrument provides:

- a portfolio-based credit risk protection by LIFE Programme, provided by means of cash-collateral (Risk Sharing Facility);
- a long-term financing from the EIB (EIB Loan for Energy Efficiency);
- consulting services for the Financial Intermediaries (Expert Support Facility).

A scheme of the PF4EE concept is shown in Figure 9.

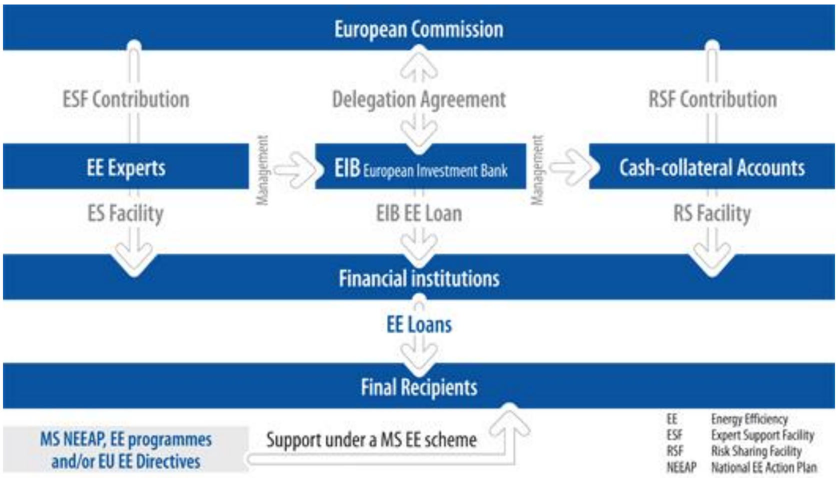

Figure 9: PF4EE Concept [38]

Currently, the PF4EE instrument is available through local commercial banks in eleven EU Member States: Czech Republic, Spain, France, Belgium, Italy, Portugal, Croatia, Greece, Cyprus, Poland, Latvia. In the different Member States, the focus is on different targets based on the specifics of the local economy and energy systems; for this reason, the technical eligibility criteria are different according to the specific focus, but typically are based on the investment belonging to a list of standard measures for low-CAPEX ones and on meeting specific criteria on relative energy savings and NPV of the investment for medium- and high-CAPEX ones (up to 10 million € of project cost and 5 million € of covered loan).

Another credit facility worth being mentioned is the European Local Energy Assistance (ELENA) Facility [43], implemented by the EIB in agreement with the EC. It was first established in 2009 under the Intelligent Energy-Europe (IEE) II Programme and is currently financed by EU under Horizon 2020. ELENA can be used to assist Member States to achieve their energy efficiency objectives under the Energy Union strategy, through projects assisting cities and regions to increase the quality of living and decreasing energy consumption. The Facility provides grant support to cover up to 90% of the costs of Project Development Services (PDS) for the preparation of eligible Investment Programmes.

The Facility aims at supporting the actions of public and private stakeholders at local, regional and national level, in order to stimulate a broader utilisation and market uptake of innovative solutions, including technologies, processes, products, policies, organisational models and practices. Its objective is to accelerate investments by way of increasing the level of local experience and expertise, while also facilitating financing and helping to overcome existing investment barriers.

ELENA provides support to three distinct sectors and for that purpose, three tailored envelopes are available with slightly different eligibility rules:

- Sustainable Energy: general energy efficiency and building-integrated renewables;
- Sustainable Residential: energy efficiency and building-integrated renewables in existing residential buildings;

- Sustainable Transport: innovative urban transport and mobility projects resulting in energy and emissions savings.

The projects eligible for ELENA support have a mobilized investment of more than 30 million Euro and an implementation period of 3 years for energy efficiency and 4 years for urban transport and mobility. The activities covered by ELENA grants include:

- feasibility and market studies;
- programme structuring;
- business plans;
- energy audits and financial structuring;
- preparation of tendering procedures;
- contractual arrangements;
- project implementation units.

To conclude, the GEFF programme includes a set of initiatives developed by the EBRD and many other international donors (national bodies and supranational entities and funds), which support businesses and sometimes citizens willing to invest in green technologies. Eligible projects are related not only to energy efficiency or renewable energy but also to water and resource efficiency, circular economy and climate change mitigation and adaptation. The GEFF programme operates through more than 140 local financial institutions across 26 countries with almost 4 billion Euro of EBRD finance; over the last years, more than 130,000 clients benefitted of the programme, collectively avoiding almost 7 million tCO_2/y of GHG emissions.

The GEFF programme is not only providing simple lines of finance; indeed, an experienced team of bankers and technical programme managers at EBRD ensures consistent quality and innovation in the GEFF product and service delivery. In addition, project consultants are hired by EBRD to provide advisory services to help participating financial institutions and their clients enhancing their market practices. The eligibility criteria for GEFF are slightly different from initiative to initiative, but typically they include a maximum investment of few million Euro, a minimum IRR of 10% for energy efficiency projects and 0% for renewable energy projects, and an energy saving ratio of at least 15-20% compared to the baseline situation. [38]

4.2.4 NESOI Islands Facility

NESOI – New Energy Solutions Optimised for Islands is a project funded by the European Union under Horizon 2020 programme, started in October 2019 and ending in September 2023, whose aim is to unlock the potential of the EU islands to become the locomotives of the European Energy Transition. To achieve so, NESOI is promoting the green energy investment to an audience of 2,400 inhabited island giving also the opportunity to test the new innovative energy technologies in a cost-competitive way. [11]

Indeed, islands have to understand which are the most relevant opportunities for their ecosystem, starting from the redaction of energy transition planning documents to the implementation of consolidated and innovative technologies for RE, Energy Efficiency (EE), Storage and Clean Transport. Moreover, to ensure that the technologies implemented are in line with the European green goals, NESOI will work in strict contact with the Clean Energy for EU Islands Secretariat bringing it one step forward by providing to islands training, technical support, cooperation opportunities and robust funding opportunities to concretely convert Islands' Plans into Renewable Energy Sources plants, building and energy infrastructure retrofitting, energy bills reduction, local job creation, etc.

The ultimate goal of NESOI is to facilitate the decentralization of energy systems and contribute to EU policy in achieving 2030 climate targets. This will be achieved by mobilising more than 100 million € of investment in sustainable energy projects to an audience of 2,400 inhabited EU islands and give the opportunity to test innovative energy technologies and approaches in a cost-competitive way. The specific objectives of NESOI are to promote investments for energy transition in the islands, facilitate the decentralization of energy systems, contribute to EU policies and the achievement of 2030 targets by: 440 GWh/y primary energy savings and 160,000 ktCO_2/y of GHG emissions avoidance.

To that end, NESOI aims not only to provide first-step financial support for islands energy transition investment plans and projects, but also to provide technical assistance and coaching through the NESOI experts to develop and implement energy transition plans or sustainable energy-related projects. Successful proposals selected through dedicated open calls, the first closed in December 2020, receive financial support up to EUR 60,000 lump sum in the form of a grant to procure external technical assistance advisory service (local advisors) for development of the energy-related action, plus technical assistance for the same economic value provided by the NESOI Consortium.

Beneficiaries shall develop the energy-transition projects over a period of 6-12 months, during which NESOI will provide a wide range of Technical Assistance portfolio. On the one hand, from NESOI experts' team, which can provide specialised technical assistance services, according to the portfolio of services (i.e. planning documents, feasibility study, due diligence, support in tender procedures for PPP, support to local authorities for evaluation of PPP proposals, support in application to technical assistance programs/funds, economic and financial modelling and fund matching); on the other hand, from external experts through direct financial support (cascade funding, i.e. transfer to final beneficiaries of part of the grant received from the European Commission by NESOI) complementing the technical assistance provided by NESOI experts in particular for local and/or country-specific activities. In addition, NESOI will supplement the initial technical assistance activities by longer-term coaching activities to ensure that project promoters have got increased capacity for developing investible energy transition projects. [11]

4.2.5 Additional Support Mechanisms for Energy Transition Projects

This paragraph focuses on other types of support mechanisms for energy transition projects, specifically for energy efficiency and renewable energy projects, which are those incentivizing the operation rather than the realization of energy transition projects. These incentives include white certificates for energy efficiency projects and green certificates, feed-in tariffs and net metering for energy production from renewable energy sources [44], [45]. These support mechanisms are described in the following paragraphs and typically are applicable also on islands without significant differences from the application on the mainland.

White certificates are tradable certificates generated from the implementation of energy-saving measures; one certificate corresponds to a certain amount of primary energy saved, typically 1 toe (ton of oil equivalent). Their value is generated on the market, as a balance between the offering of certificates from Energy Service Companies implementing energy efficiency projects and the demand of operators of the energy market (electricity/natural gas) that are obliged to achieve a certain yearly amount of energy savings either with direct interventions or with the purchase of white certificates on the market.
White certificate schemes typically allow the implementation of energy efficiency activities in buildings and small and medium enterprises facilitating an up-front discount. The amount of white certificates for a given project is determined according to well-defined rules and procedures, which differ from a type of energy efficiency project to another. This quantification shall be done by accredited companies

and validated by a regulation authority, which also manages the market for the trade of certificates and is responsible of monitoring and management of the whole process.

Similarly to white certificates, green certificates (or renewable energy certificates – REC) [46], Article 19, are tradable certificates generated from the production of energy from a renewable source; one certificate corresponds to a certain amount of primary energy saved, typically 1 MWh. Their mechanism is in principle exactly the same of that presented for white certificates, with their economic value that is formed on the market, as a balance between the offering of certificates from renewable energy systems operators and the demand of operators of the electricity market that are obliged to achieve a certain yearly amount of energy produced from renewables either with direct interventions or with the purchase of green certificates on the market.

A feed-in tariff is an incentivization mechanism typically designed to promote investments in renewable energy sources; it means granting small-scale solar or wind energy producers a price above the market value for the energy they produce and deliver to the grid. These tariffs are generally needed only to promote the exploitation of renewable sources in the early stages of their technology development, when they are not economically profitable compared with other conventional options. Feed-in tariffs typically involve long-term agreements (15-25 years) and prices significantly higher than the market values. The long-term nature of the contracts and the guaranteed high rewards aim at protect investors from risks that would otherwise obstacle the realization of the investment. Moreover, this kind of incentive guarantees that also small-scale energy producers have access to the grid. Besides feed-in tariffs, also feed-in premiums, whereby eligible renewable energy generators are paid a premium price, which is a payment in addition to the wholesale price, are applicable for medium-large RE installations in the EU ([46] art. 4 – 'Support schemes for energy from renewable sources'), see guidelines [47].

To conclude, the last support mechanism worth being mentioned is net metering, suitable for auto-producers of electricity, i.e., entities producing electricity from renewables and feeding it into the grid and at the same time purchasing electricity from the grid for own consumption. The net metering concept foresees that they can benefit of a compensation of the economic value on the difference between the production and the consumption of electricity. This is an incentive since typically the market price for the sale to the grid of power generated is much lower than the purchase price of electricity from the grid. Currently, net metering is not applicable in EU member states

4.3 Islands' Support Needs for Energy Transition

This section focuses on the identification of islands' support needs in terms of energy transition projects; the analysis is carried out by analysing the different types of projects that can fall under this category, their features and the stakeholders that they usually involve.

The categories of projects covered in the analysis are:

- electricity production from renewables;
- thermal production from renewables;
- cogeneration of heat and power;
- electric mobility;
- energy storage;
- upgrade of local public assets;
- energy efficiency in buildings.

4.3.1 Electricity Production from Renewables

This technology cluster includes projects for electricity production from sources like solar, wind, biomass, geothermal, hydro and wave/tidal. Projects foreseeing the installation of systems and plants for self-production of electricity from solar radiation (and sometimes also from wind) may be implemented by any type of stakeholder, from individuals, energy communities or small companies as buildings' owners to large private complexes (industrial or commercial sites), to public buildings (schools, hospitals, etc.).

On the other hand, large utility-scale plants such as solar or wind farms, power generation plants from biomass, hydro or geothermal source are usually realized by the local utility or a private company in agreement with the utility and/or grid operator and/or authorities.

As most of the technologies are characterized by a high maturity and availability, for private installations generally no support from public entities is needed and projects can be implemented with investors' own funds or conventional loans from banks, since they are typically able to generate cash flows to repay the loan in a reasonable timing; on the other hand, for large-scale installations, support from institutional investors and/or funds may be needed.

In relation to the SMILE demonstration projects discussed in Section 3.1, such production units can be found on each of the SMILE islands. Samsø's demonstration project at the Ballen Marina includes new installations of PV capacity, Orkney is addressing the implementation of local electricity production from wind turbines, and Madeira is working with both the integration of PV production, as well as balancing the overall production, including from wind turbines, into the autonomous electricity grid.

4.3.2 Thermal Production from Renewables

This group of technologies includes solar thermal, biomass and geothermal technologies for heat production. Small scale units for self-production of heat may be implemented by any type of stakeholder, ranging from individuals, energy communities or small companies as owners of single buildings, to large private complexes (hotels, supermarkets, industries), to private buildings (schools, hospitals, offices, etc.). Large-scale exploitation of these technologies can be foreseen only in case of integration into a district heating system, therefore the investment needs to be promoted or at least involve the local DH operator and the local authorities.

Similarly to the previous technology group, this type of projects is characterized by a significant high maturity and market availability for the main components, thus for private use they can be realized with own funds or conventional loans with banks. Only infrastructural projects related for instance to district heating in cities can be supported by the local municipality and/or by institutional national or EU funds.

While the SMILE project and demonstration islands focus on the electricity production and balancing, certain thermal production can also be found in the SMILE islands, as well as islands globally. For example, Samsø and Orkney both have substantial heat demands and are addressing it though partially through power-to-heat installations, but also solar thermal collectors and biomass boilers are typical on both islands. Also Madeira could make use of either option, though with a different demand profile; while geothermal is limited to geographical regions not covered in the SMILE project.

4.3.3 Cogeneration of Heat and Power

Similarly to the previous group of technologies, two main possible cases are identified for this solution:

- combined heat and power production plants to self-produce thermal and electric energy can be installed by any type of stakeholder with size depending on its energy needs;
- larger project at island level, including the installation of a larger CHP plant are typically agreed with the local DSO and/or DH operator and the relevant local authorities.

Also in this case, technologies are consolidated and widely available; in the former case of the list, the investment is generally done with own funds or supported by banks with conventional loans; in the latter case, similarly to renewable-heating systems, projects related to district heating can be supported by the local municipality and/or by public national or EU funds.

This presents an option, not only to the SMILE islands, but generally, though the large scale installations are often limited to highly populated and/or interconnected energy systems, which is not the case on either Samsø, Orkney or Madeira. Small-scale solutions could be more feasible in this context.

4.3.4 Electric Mobility

Large-scale solutions for electric mobility on the island, such as the realization of a charging infrastructure and the increase of the penetration of EVs can be promoted by private companies (including suppliers of such services on the mainland, but also operators of public assets on the island, like public transport providers) but generally are supported by the municipality or another local authority. Also, individual citizens or energy communities, or private companies (especially if working in logistic activities on the island) may realize private investments in this field for their own vehicles and private charging stations.

If implemented as infrastructural investment, this kind of project typically receives strong support by public entities, either directly from the municipality/region or authority balance or recurring, directly or indirectly, to national or EU structural funds.

As also highlighted, especially in the Madeira SMILE context, the alignment of electric mobility with the energy system development and its markets is of high importance, not just for islands. Both the uptake of the EVs, as well as the infrastructure require support. Also, Samsø's Ballen Marina covers a niche of electric mobility, as well as the EVs on Orkney, which support this claim.

4.3.5 Energy Storage

This kind of solutions, related to electricity storage (battery or pumped-hydro) or thermal energy storage, as well as green fuel storage like hydrogen tanks, are of interest of the grid operators on the island (DSO for electricity, DH operator for heat, if present), or of utilities and private companies interested in selling this kind of service to grid operators. However, they might be of interest also for energy communities and final users.

They are generally implemented with own funds by the companies, but being projects related to local infrastructures they may receive support from local authorities, as well as from national or European funds.

In SMILE, electricity storage plays a major role, not only for the grid operator, such as on Madeira, but also for local optimisation of e.g. PV production, such as at the non-injecting PV owners on Madeira

('UPACs') or the marina on Samsø. WP8, especially D8.2, however, also points out the great potentials of thermal storage, in combination with heat supply, for both DH and individual users; as well as the potential of hydrogen/fuel storage in combination with existing (cf. Orkney) or future hydrogen/fuel production. However, according to EU and UK law, DSOs are prohibited from owning and operating storage, besides some exemptions. For the case of Orkney and Samsø, they can only buy the flexibility service from storage owned and operated by companies, energy communities, etc.

4.3.6 Upgrade of Local Public Assets

All the solutions of this group of technologies are applied to public assets, such as electricity distribution grid, public lighting systems, ports, water/waste treatment facilities, therefore it is clear that these projects are generally promoted by the operator of the public asset subject of the refurbishment, where needed with the support of third private companies and/or of the municipality or other local authority.

For these infrastructural projects, which are related to services to islands' inhabitants and companies, and sometimes being also enabling technologies for further activities , a strong support from the public sector is expected, either directly or recurring, directly or indirectly, to national or EU structural funds.

While not playing a large part in the SMILE project, upgrades of local public assets are of importance to every energy system, including the ones being part of SMILE, and should therefore always be strived for. The same applied to the next sub-section of energy efficiency. Both improvement types are not further elaborated in SMILE, but play an important part in the creation of future energy system scenarios, as were created in report D8.2.

4.3.7 Energy Efficiency in Buildings

The interventions for the improvement of energy efficiency of buildings cover interventions on lighting, heating and cooling systems, thermal insulation of envelope and windows, building automation and energy management systems, smart metering, district heating and cooling.

Since most of these actions are related to single buildings, they might be realized by any kind of stakeholder, including:

- municipality and other local entities for public buildings (e.g., schools, office buildings, hospitals, etc.);
- private entities (e.g., industries, tertiary complexes, private buildings, energy communities, etc.) for own buildings.

The only solution not focusing on a single building is the realization/upgrade of a district heating (or cooling) network, which shall be promoted by the municipality or other relevant authority or by the company operating the DH (or DC) network.

Projects related to energy efficiency in buildings generally rely on consolidated technologies and components, available on the market. These projects are generally able to generate savings that are sufficient to repay the investment; thus, depending on the kind of intervention, these projects are implemented with own funds or supported by banks with conventional loans, or even realized by Energy Service Companies.

4.4 Matching Islands' Needs with Available Instruments

It is widely acknowledged that energy transition of islands can become one of the drivers of the EU decarbonization pathways. Indeed, on one hand islands can become laboratories for the implementation of technical solutions related to smart integrated grids with good replication potential in the mainland; on the other hand, interventions done on islands can have a higher impact compared to the same action done in the mainland, due to local peculiarities such as the local energy mix, typically relying on fossil fuels and therefore implying high environmental impact and costs, the weaknesses of the local grids and the related level of energy poverty, the high value of the local ecosystem.

Nevertheless, financing the energy transition of islands seems to be more difficult than decarbonizing the mainland energy system; indeed, as seen in the previous chapter and sections, on one hand there are no financial instruments tailored for islands and on the other hand islands suffer from a number of obstacles. Among the identified barriers to financing energy transition of islands, the following ones are worth being mentioned:

- lack of specific experience and technical expertise among the actors involved in the financing process, in case of absence in their project portfolios of similar projects implemented in similar contexts;
- absence of well-defined energy plans or targets in many islands, which is an obstacle to the identification and prioritization of investments and a limit for the attractiveness of projects for external stakeholders;
- the limited financial capacity and guarantees/collateral of the local stakeholders, which generally are smaller compared to the same actors present on the mainland;
- in islands with high seasonality (presence of inhabitants and consequent energy consumptions) the profitability of the investments can be significantly lower, thus the payback significantly longer, compared to the same investment in the mainland.

In order to overcome these barriers, the following recommendations to policymakers can be drafted:

- support the implementation of pilot projects on islands, which can demonstrate the technical feasibility and the economic profitability of many energy transition solutions, thus creating the technical and non-technical knowledge that is currently missing among the different stakeholders involved in the financing process; in this direction the work done by the European Commission under the Horizon 2020 programme is fundamental since it supports activities aimed both to technical demonstration and knowledge creation and dissemination;
- support islands in the definition of an energy transition plan aimed at analyzing their energy consumptions and balances, identifying and prioritizing the potential interventions towards decarbonization; to this aim, a great work is being done by the Clean Energy for EU Islands Secretariat and by NESOI project, both financed by the European Commission;
- create market-based support mechanisms that are tailored on the needs of islands, including among others instruments for the incentivization of energy production from renewables and energy efficiency on islands, whose environmental and social value is generally higher than on mainland;
- dedicate a part of the existing funding instruments at EU and national levels to the transition on islands, given the possibility to use them as test-based;
- consider that they are usually economically and socially suffering from the consequences of isolation;
- create/implement local flexibility schemes (e.g. market-based), depending on local conditions and economic feasibility in order to mobilize flexibility [20].

To conclude, the following paragraph presents an additional recommendation, related to the proposal of a credit facility aimed at supporting the energy transition of islands.

4.5 Proposal for a Credit Facility for Islands' Energy Transition

In the bankability analysis carried out within the ReUseHeat project [38], RINA Consulting has proposed the creation of a credit facility for urban excess heat recovery investments, which has been presented and discussed in several events with relevant stakeholders and institutions. Although the focus of the SMILE project is different, most of the features of such a credit facility are valid and worth being proposed also for investments in energy transition of islands.

Indeed, the previous sections have shown that financing this kind of projects is often considered as risky by many commercial banks, unless a number of conditions are met. The presence of a guarantee from the public sector is considered by banks as a positive aspect in the decision-making process and such experiences already exist in the field of energy efficiency / renewable energy projects.

The creation of a pilot credit facility for financing project for energy transition of islands is therefore proposed, which foresees that part of the risk related to funding is borne by a public body recognizing the strategic importance of these projects for the decarbonization of the EU energy system. This is in line with the approach applied in the NESOI project, which however provides technical and financial support only for the realization of planning documents, feasibility studies and design of energy transition projects on islands and not for the realization of the projects themselves.

The proposed credit facility foresees a long-term financing made available by an Institutional Bank, acting as sponsor, to one or more Commercial Banks in the EU and the issue of a credit guarantee fund by national or supranational entities aimed at covering risks related to the performance/availability/delay related to the technology or the renewable/heat source. The risks related to the default of the project proponent or to other financial causes are not covered by the public guarantee and are borne by the commercial bank as per the usual credit evaluation and management procedures. Within this scheme, the key incentive would be constituted by the risk-sharing facility rather than by the credit line, since the discussion with many stakeholders highlighted how the lack of liquidity for banks in the EU is nowadays not a key issue.

In addition to the sponsor, the partner banks and the institutional entities, a key role in the support to the credit line is played by a consulting company, which is awarded by the sponsor with the provision of support to all the involved parties. The Project Consultant supports the sponsor and the partner banks in the definition of the procedures and forms of the credit facility and in the monitoring of the progress of the facility as a whole and of single projects, evaluates the requests for funding and provides technical support to applicants.

The proposed pilot facility, having a duration of at least 3-4 years and a total capacity of 20-30 million Euro with maximum 2-3 million Euro per project, works according to the following cycle:

- the entity requesting the loan submits an application form to the selected commercial bank with attached technical documents regarding the energy transition project;
- the commercial bank evaluates the creditworthiness of the applicant and, if positive, forwards the technical documents to the project consultant;
- the project consultant carries out a preliminary technical assessment, based on the design documents made available and on the discussion with the project proponent taking place during a dedicated site visit; the output of the assessment is a report validating the

technological concept and the cash flow model under a technical perspective and providing recommendations for improvement, if any, to the project proponents;

- based on the creditworthiness verification and on the technical validation, a loan agreement is signed between the commercial bank and the project proponents;
- the project proponent implements the project according to the schedule attached to the application form; the project consultant monitors the progress of the project implementation and provides the commercial bank with periodic updates, especially in case of deviations; at the completion of the project, the project consultant evaluates the consistency of the implemented project with the initial statement and with the objectives of the credit facility;
- the project proponents carry out periodic evaluation of benefits related to the implemented project after the start of operation and submit data to the project consultant that provides periodic updates to the sponsor and the institutional bank on the results of the credit facility;
- in parallel to the above described activities, the project consultant supports the sponsor and the partner banks and provides periodical reports to the sponsor regarding the number of applications and requested loan amounts, the signed loans, the progresses in projects implementation, the achieved energy and environmental benefits, etc. [38]

5 Conclusions

This report on the energy market analysis with recommendations continues the work of SMILE WP8, where energy systems of the three demonstration islands are analysed and how their scenarios are best implemented when taking into account the market. In relation to the previous project activities (Tasks 8.1 and 8.2), this report discusses and recommends the realisation of the transition to high RE on the SMILE islands as well as beyond and in a more general context. On the one hand, Chapter 3 points out the necessity to evaluate the transition on the islands and identify the institutional barriers, on the other hand, Chapter 4 indicates which support mechanisms can help in that regard in a broader context.

While the SMILE technologies and approaches are technically realistic, the need to align their development is highlighted through examples on Samsø, Orkney and Madeira. Where D8.2 presents technical future scenarios, this report addresses their implementation. After presenting the situation on each island, transcendent solutions are discussed and recommendations made. These include the required support for RE capacity investments as well as for smart technologies, such as heat pumps, EVs and smart chargers, or balancing technologies. Furthermore, the alignment with the market requires incentives for a flexible and dynamic consumption, according to RE production, for which the technologies present a prerequisite. A better inclusion of the consumer is therefore also recommended to allow future 'smart consumption' of energy and through appropriate price signals and presenting the true cost of energy.

After presenting the different potential support mechanisms for energy transitions on islands, but also elsewhere, the islands' needs are presented and support gaps identified to match them with available instruments. Proposals to bridge the gap include the demonstration of technical feasibility and economic profitability of many energy transition solutions on islands, support islands in the definition of an energy transition plan, create market-based support mechanisms, as well as a proposal for a credit facility.

Besides the market and support recommendations for the energy transition to higher RE shares on islands, the political alignment needs to be addressed in a concluding next step. This is further presented in the report on Policy strategy recommendations (SMILE D8.5), which finalises the work on WP8 in the SMILE project.

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