Reference energy simulation models for the three pilot islands (Samsø, Orkney, Madeira)

Smart Island Energy Systems - H2020 Project SMILE Deliverable 8.1

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Reference energy simulation models for the three pilot islands

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Keywords, Acronyms

AAU	Aalborg University
BESS	Battery Energy Storage System
BMS	Battery Management System
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
DSM	Demand Side Management
DSO	Demand Side Operator
EEM	Electricity Company of Madeira (Empresa De Electricidade Da Madeira Sa)
EMS	Energy Management System
EV	Electric Vehicle
JP	Jet Petrol
LPG	Liquefied Petroleum Gas
Li-on	Lithium-ion
MERRA	Modern-Era Retrospective analysis for Research and Applications (Weather data)
PES	Primary Energy Supply
PP	Power Plant
PV	Photovoltaic
RES	Renewable Energy Source
RAM	Região Autónoma da Madeira
V2G	Vehicle To Grid
VDP	User Datagram Protocol
WP	Work Package

EnergyPLAN – modelling tool for the analysis of the whole energy system by identifying and exploiting technologies and synergies across sectors (also referred to as smart energy systems) by AAU
Load curve – is a chronological chart that illustrates the variation in electricity or other energy demands
Self-consumption – electricity that is produced from renewable energy sources, not injected to the distribution or transmission grid or instantaneously withdrawn from the grid and consumed by the owner of the power production unit.
Smart charging – charging techniques, which do not follow the normal plug and charge paradigm.
(in kW or MW) over a specific time.
Web-service – an application that in the context of this project, displays energy production information using the Internet.

1 Introduction

In this report, we present the specification and assessment of *Task 8.1: Establishing reference energy simulation models* for the three Pilots, which is in the scope of the SMILE project work package (WP) 8. 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.

The three pilot islands Samsø, Orkney and Madeira are all investigating ways of becoming carbon neutral, though local conditions differ widely. While the Orkney Isles and Samsø are connected to the rest of Denmark and the United Kingdom respectively, Madeira is an isolated stand-alone system. Samsø and the Orkney Isles also both have significant heat demands, while Madeira has a warmer climate. In terms of population, they range from Samsø with 3,700 inhabitants via Orkney with approx. 21,000 inhabitants to Madeira with about 250,000 inhabitants, influencing demands and available resources. All islands present a unconventional energy system shaped by its surroundings; Samsø has been undergoing a decade-long transition after winning an energy island competition, the Orkney Isles are characterised by a large number of wind turbines and offshore testing facilities, and Madeira lies far off the European continent and stands out in European terms with great solar potential. These islands are therefore sites with good potentials for renewable energy production, which is addressed within the SMILE project.

This report's Chapter 2 gives an outline of the contents and aims of WP8 in order to establish the framework for this deliverable and the reference simulation models. Next, the main tool applied for energy systems simulation is presented: the hourly EnergyPLAN model.
Chapter 3 presents the regional demonstrators and the individual pilots in terms of the relevant energy systems characteristics necessary to establish simulation models. Thus, it contains energy system overviews, including details of supply, conversion, as well as demand sides. With this, the reference models are presented in that Chapter with the underlining information on what they are build upon.
After presenting the islands separately, a comparison allows for the evaluation of similarities and differences in Chapter 4. This Chapter sums up the main data resulting from the reference models and gives and overview of applied data. Additionally. It allows for a validation and discussion of the before presented models of Samsø, Orkney and Madeira.
Chapter 5 briefly concludes the Deliverable 8.1 and introduces the next Task and Deliverable 8.2.

2 Clarifications

This Chapter presents clarifications that are necessary for a full understanding of this report. Therefore, a review of WP8 with its objectives, tasks and deliverables is performed, before going into detail with D8.1 and the approaches taken for its achievement. Further, the EnergyPLAN model is presented as it forms the base for the deliverable.

2.1 Review of Work Package 8 (WP8)

Within the Framework of the SMILE project, the main goal of WP8 is to analyse and present the pilot islands' energy systems and the impacts, strategies and energy market designs associated with the pilot projects. The details of its objectives, tasks and deliverables are listed below.

2.1.1 Objectives

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 of the demonstration projects and their role in such high-RE scenarios. Primary focus is on the short and midterm. Secondly, the WP investigates the energy market structures and policy strategies that impact and are impacted by the transition process in the three pilot islands. This is achieved through meeting the following objectives:

- Establishment of reference energy systems simulations models of the three pilot islands.
- Establishment of medium term (10-15 years) high RE scenarios for the three pilot islands.
- Establishment of recommendations for market design structures to support the transition to high-RE energy systems in the three pilot islands.
- Establishment of policy strategies to support the transition to high-RE energy systems in the three pilot islands.

2.1.2 Description of work and roles

WP8 - Impact analyses: Energy system impacts, energy strategies and energy market design [Months: 1-42]
AAU, RINA-C, CES, Sunamp, ACIF-CCIM, EEM, MITI, PRSMA, SK, SE, DTI, LIBAL, SEV, CERTH, RUG, DAFNI

Task 8.1: Establishing reference energy simulation models for the three Pilots for modelling a year with a temporal resolution of 1h (Task Leader: AAU PLAN, Duration M1-M6)

Task 8.2: Establishing and simulating short-term high-RE scenarios for the 3 pilots (Task Leader: AAU PLAN, Duration M6-M20)

Task 8.3: Power loss management of minutes based energy outages in the distribution grid of the three islands, with simulation tools (Task Leader: CERTH, Other participants: AAU PLAN, Duration M35-M42)

Task 8.4: Energy market design structures to support the transition to high-RE energy systems in Orkney, Samsø and Madeira islands (Task Leader: AAU PLAN, Duration M30-M36)

Task 8.5: Policy strategies to support the transition to high-RE energy systems in Orkney, Samsø and Madeira islands (Task Leader: AAU PLAN, Duration M36-M42)

2.1.3 Deliverables

Deliverable Number	*Deliverable Title*	*Lead beneficiary*	*Type*	*Dissemination level*	*Due Date (in months)*
D8.1	Reference energy simulation models for the three pilot islands	10 - AAU	Report	Public	9
D8.2	Medium term scenarios for the three pilot islands	10 - AAU	Report	Public	20
D8.3	Minutes-based power loss management towards a 100% RES island	17 - CERTH	Report		42
D8.4	Energy market recommendations	10 - AAU	Report	Public	42
D8.5	Policy strategy recommendations	10 - AAU	Report	Public	42

D8.1 : Reference energy simulation models for the three pilot islands [9]

Report describing the established reference energy simulation models of the energy system for the three pilots for modelling a year with a temporal resolution of 1h. This reference will holistically describe the present energy systems including electricity, heating, cooling, transportation and industrial needs with a particular focus on parts of the systems that are interconnected through conversion units between these (e.g. electricity to heat or electricity to transportation). This deliverable mainly refers to Task 8.1.

D8.2 : Medium term scenarios for the three pilot islands [20]

Report describing future scenarios (short term, i.e. up to five years, as well as mid- and long term) which include the demonstration projects in the three pilot islands in the perspective of a shift from energy systems relying on fossil fuels to energy systems relying solely or exclusively on renewable energy sources. This deliverable mainly refers to Task 8.2 as well as Task 8.1, since scenarios take their starting point in the reference models developed in Task 8.1.

D8.3 : Minutes-based power loss management towards a 100% RES island [42]

Report describing measures applicable to the power loss management of minutes-based energy outages in the distribution grid of the three islands. The report will include suggestions for a variety of supporting power production systems along with storage solutions capable of filling the power demand for these very short time scales. This deliverable mainly refers to Task 8.3.

D8.4 : Energy market recommendations [42]

Report providing recommendations for potential changes in energy market structures to support the transition to high RE energy systems in Orkney, Samsø and Madeira islands. This deliverable mainly refers to Task 8.4.

D8.5 : Policy strategy recommendations [42]

Report providing recommendations for potential changes in policy strategies to support the transition to high-RE energy systems in Orkney, Samsø and Madeira islands. This deliverable mainly refers to Task 8.5.

2.2 Review of Deliverable 8.1

Deliverable 8.1 presents the result from the corresponding Task 8.1, which focuses on modelling reference scenarios for the three pilot islands. This is approached on an hourly resolution, including a whole reference year from January 1st to December 31st. This way, differences of seasons, weekdays and daytimes are considered. This is important when analysing present and future energy scenarios characterised by a strong or increasing connection between sectors and by increasing shares of fluctuating renewable energy based productions. The reference models are generally defined through the existing energy systems and available data related to it at the time of the Task 8.1. Depending on the availability of data at the different pilot islands, the reference models are created. This is further explained in detail in the corresponding Chapter 3.

In close relation to the Task 8.1 is the subsequent Task 8.2, which is planned to be accomplished by October 2018 (month 20). Task 8.2 is building upon Task 8.1, as it uses the resulting reference models for future simulation. A reference of high quality is therefore of importance, and the validation and consequences are further discussed in Chapter 4 and 5.

The software used for the hourly simulation of supply and demand for a complex energy system is EnergyPLAN, developed at Aalborg University. This model is introduced for clarification in the following.

2.3 EnergyPLAN

The EnergyPLAN model is used to simulate the electricity, heating, cooling, industry, and transport sectors of an energy system, depending on the scope and inputs. It simulates each sector on an hourly basis over a one year time horizon and can be used on various geographic levels and sizes of energy systems. It simulates the mix of technologies in the whole system by identifying and exploiting synergies across the sectors. It is able to model fluctuating energy sources such as wind and solar, and simulates their effects on the rest of the energy system. Depending on the inputs, such as technology capacities, efficiencies, and costs, as well as the demand and supply of the investigated case – here of three islands – various simulations become possible. [1]

EnergyPLAN is not an investment optimisation model in the sense that there is no internal energy system design optimisation procedures; it rather simulates the optimal behaviour of an exogenously defined energy system. This may, naturally, be used for investment optimisation, but it is a user-driven process. Its simulation approach is either technical or economic. While an economic market simulation in EnergyPLAN focuses on the most economically feasible operation of the energy production units, the technical simulation focuses on technological and system efficiencies and, therefore, environmental impact. A key difference is that using economic optimisation, dispatchable units operate according to an external electricity market and modelled systems will import electricity from the market if cheaper and vice versa increase production and export more if market prices are higher than production costs.

The technical simulation is chosen for presenting the reference models and is made to function as basis for comparisons, simulating the current energy system with its demand, supply and individual specifications. The reason to use the technical optimisation is that for the future scenarios based on high degrees of fluctuating renewable energy sources, there is no credible market data to optimise against. Secondly, the analysis come in two steps. Once it has been determined what is technically possible and feasible, Task 8.4 will look more into the energy market impacts and how energy market impacts technical possibilities.

Energy simulations are usually done for reference scenarios and new (often future) scenarios to allow a comparison. The reference models are adjusted to fit to a reference year for which sufficient data is available. This can then be compared to new simulation models that include other technologies or changes in demand and supply profiles.

New scenarios have their starting point in the reference model, but aim at the suggested changes in the energy system and simulating their effects. This way it simulates close-to-realistic situations. The resulting relevant effects that can be shown may include primary energy supply (PES) shares, CO_2 emissions, import/export balance, annual socio-economic costs, etc. The new scenarios can reach from modelling small changes, e.g. new PV panels, to extensive changes, e.g. combinations of new technologies, efficiencies or demands. An ensuing comparison to the reference model shows the consequences of the specific system changes and helps quantify the impact of different technological choices or change of influencing factors.

Task 8.1 results, therefore, in the presentation of three EnergyPLAN models, one for each demonstrator island in SMILE. The respective local partners review these models to ensure that they represent the islands to the best extent possible, before being presented in Chapter 3. While these are referred to as the reference models presenting the various reference energy systems for a specific recent year, the future models, which will be developed under Task 8.2, present high-RE scenarios for Samsø, Orkney and Madeira. These are based on the reference models, but include the respective technological additions as part of SMILE (see D2.1, D3.1 and D4.1). Furthermore, probable future changes in the energy systems are adapted at the same time. The result is a second set of three EnergyPLAN models.

Figure 1 shows the possibilities of interconnections and technologies that can be studied with EnergyPLAN. It points out the opportunities of a highly interconnected energy system, while current systems are usually less complex, as the following pilot project systems in Chapter 3 show. Generally, these energy system overviews – here within EnergyPLAN and later for each pilot island's system – show supplies on the left, their application or conversion in the centre and the demands on the right.

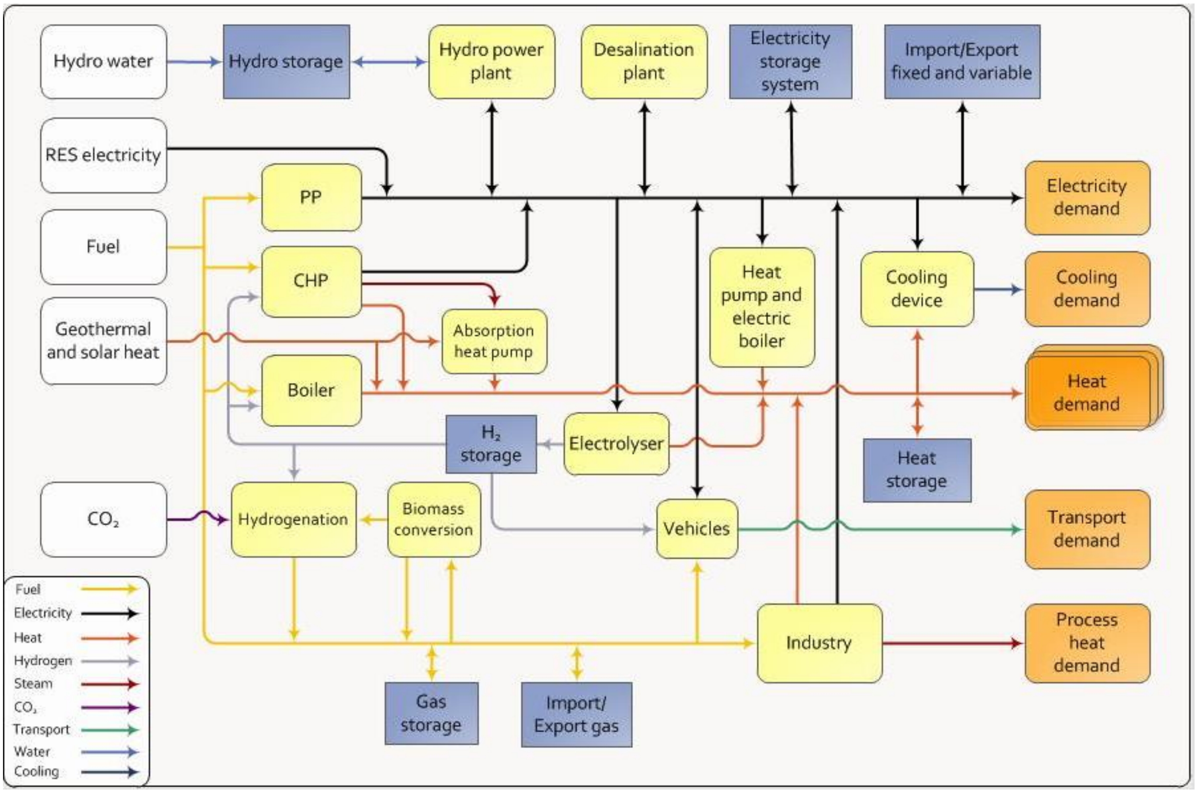

Figure 1: Overview of possible energy systems that can be studied in EnergyPLAN [1]

3 Regional Demonstrators’ Reference Models

The creation of reference models, as well as the planned high RE-scenarios of Task 8.2, take their point of departure in the demonstration of the pilot islands. Due to the individual and unique characteristics of each of them, a thorough study is made in cooperation with the project partners of the respective islands. The results are shown in the following Sections. Here, the demonstrators are presented individually before being reviewed and compared. The individual descriptions include:

- Current energy system layout
- Supply (resources, technologies, etc.)
- Energy conversion units and processes and their efficiencies
- Demands in different sectors: electricity, heating/cooling, transport, industry
- Reference model results and system overview

In Chapter 4, the pilots are compared to each other, pointing out similarities and differences, giving an overview and validation of the Smart Island Energy System simulations.

3.1 Samsø Reference Model

The island Samsø in Denmark is located on the east coast of the Danish mainland. It presents typical characteristics of Danish municipalities regarding energy supply, but also specifics related to being an exemplary renewable energy island [2]. Being part of Denmark and its ambitious targets for sustainability, district heating has become an important cornerstone to supply clusters of heat demands. The employment of wind power is another important aspect. Figure 2 presents an overview of Samsø’s energy system as of 2015, where district heating and wind power play an important part. When the wind is not blowing – and when the turbines are producing more than is locally needed – Samsø relies on the 40 MW connection to the Danish mainland for electricity export and import [3]. When imported, the electricity is mainly coming from Danish combined heat and power plants (CHP), often using coal or biomass. The emissions from imported electricity is not considered in the model.

The main focus of Samsø’s energy system lies with the locally produced electricity and the aim to use it more locally. Strengthening the reputation of being the renewable showcase island as well as strengthening the community are main goals, aiming at a secure future for the island and its inhabitants. Figure 2 illustrates the current energy system set up as seen in the modelling tool EnergyPLAN and shows the reference energy model. While Figure 2 shows supplies on the left, their application or conversion in the centre and the demands on the right, the details are presented in the following Sections.

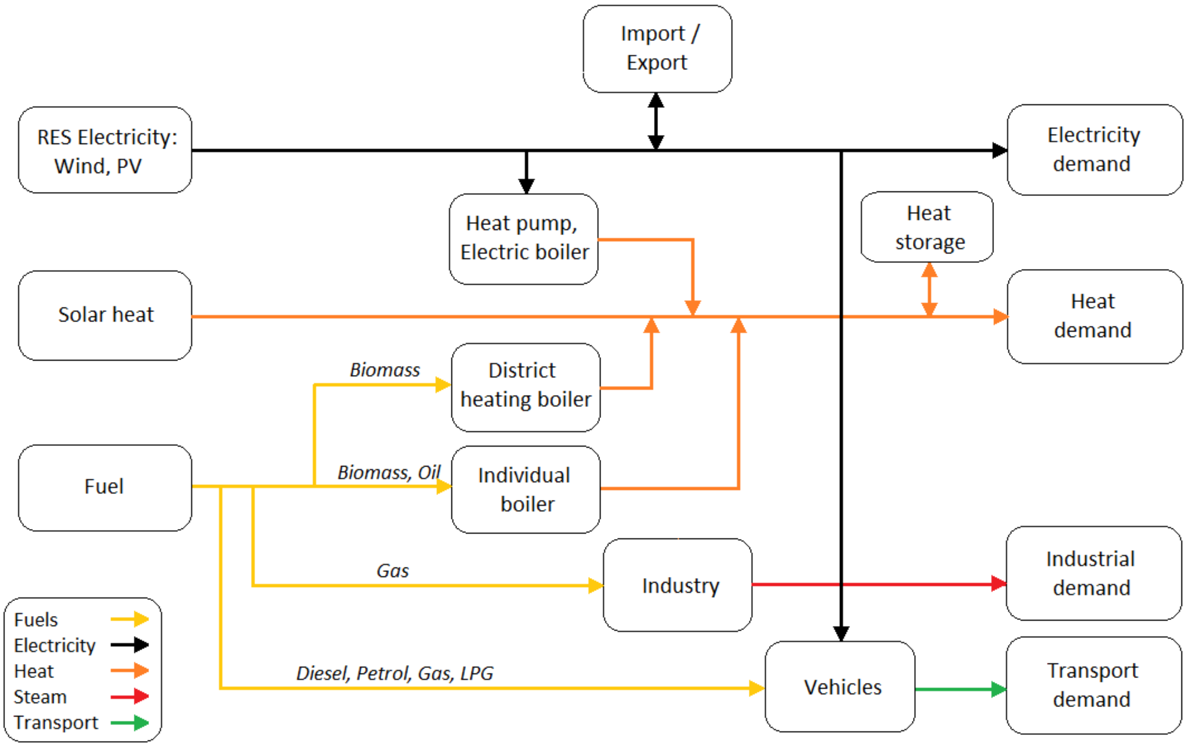

Figure 2: Overview of the energy system of Samsø

The corresponding values for energy demand and supply are published in the by-annual energy accounts for the municipality of Samsø and applied to the best extend in the development of the reference model [4]. With the latest publication being for 2015, the reference scenario is mostly simulating with values from that year for the pilot model Samsø. Further data, such as technical details of wind turbine and PV system capacities and distribution profiles for production as well as for consumption, are studied and added to the model in EnergyPLAN. Other sources are mentioned as applicable.

3.1.1 Supply

With a population of about 3,700 Samsø presents the smallest of the SMILE pilot islands. The demands of Samsø's inhabitants and sectors are partly supplied through exploitation of the fluctuating renewable energy resources wind and sun, but also by burning fuels, such as biomass, oils and gas. The overall supply side is presented in the following.

Installed wind capacity onshore is 11.4 MW, offshore 23.0 MW and PV capacity sums up to 1.3 MW with a distribution as shown in Figure 3 and Figure 4. Since the production of wind and PV power fluctuates each year, EnergyPLAN uses the capacities and production profiles to model the production, as well as previous average annual production values as listed in the energy account or similar.

Wind production on Samsø is registered on the Danish Energy Agency's (DEA) homepage, listing average onshore wind power production of 27.5 GWh and offshore production at 81 GWh annually [5]. Since the energy account calculates offshore wind power production differently, that value is neglected for modelling, but the DEA's values applied. PV capacity, on the other hand, is listed for each municipality in a file from the Danish Transmission System Operator (TSO) *Energinet* [6]. The production in EnergyPLAN is then modelled to fit the annual values from the energy account 2015.

Next to solar and wind resources producing mainly electricity, but also some hot water from solar panels, the island Samsø relies on the electricity imported through the two main cables connected to the mainland of Denmark with the total transmission capacity of 40 MW [3]. This line is mainly used for the export of surplus wind power and used only for a limited amount of hours for import of electricity. The nominal maximum of local production is 35.7 MW plus some minor private turbines, which are neglected in this system analysis. In the reference model, the maximum export of electricity is 30.9 MW and import is 3.7 MW per hour, depending on the local demands, leaving a possible expansion of local production of around an additional 10 MW. There is no fuel-based power generation on Samsø.

Heat, on the other hand, is supplied from four district heating plants throughout the island, which are running on woodchips, straw and solar heat; or by individual heating devices using further biomass, oil, solar collectors or electricity.

Table 1: The energy supply on Samsø [2]**,** [4], [5]

	Supply	Capacity/ quantity	Production	*Notes*
	Wind onshore	11.4 MW	27.5 GWh	[5]
	Wind offshore	23.0 MW	80.9 GWh	[5]
	PV	1.3 MW	3.1 GWh	[4], [6]
	Transmission line / Import	40 MW	1.5 GWh	[3], *EnergyPLAN output* [1]
	Solar (thermal) collectors, indv.	App. 517 m²	0.4 GWh	[4]
	Solar collectors, DH	2500 m²	1.0 GWh	[2], [4]
	Biomass	> 10.7 kt	52.2 GWh	[1], [4]
	Oils	> 7.2 kt	89.0 GWh	[1], [4], *estimation*
	Natural Gas, LPG	> 1.8 kt	23.4 GWh	[1], [4] *estimation*

Table 1 presents all the primary energy sources for Samsø. With a high share of wind power, as well as an extensive exploration of biomass, the share of renewable sources of the PES reaches 60%. Especially the transport sector and some of the individually heated buildings still require fossil fuels. When it comes to electricity needed on Samsø, 94% is produced by wind and PV and the remaining 6% is imported and therefore most likely not from RES, but the majority of the local demand is covered by the locally produced renewable electricity.

For the hourly simulation in EnergyPLAN, the wind and solar productions are specified by their distribution profiles throughout the whole year – here the reference year 2015. The following figures present these distribution profiles for wind power, PV power and solar thermal production. The profiles should origin from measurements in the studied area, presenting the real production on the respective island, but for Samsø alternative data is applied. The real wind and PV production profile for Samsø for 2015 was not available, but a renewable energy simulation website for wind and PV enables the simulation for both production profiles with numerical weather data for Samsø [7], [8]. For the wind production simulation, the most common turbine types on Samsø are taken into account (Bonus B54 and B82) for the simulation.

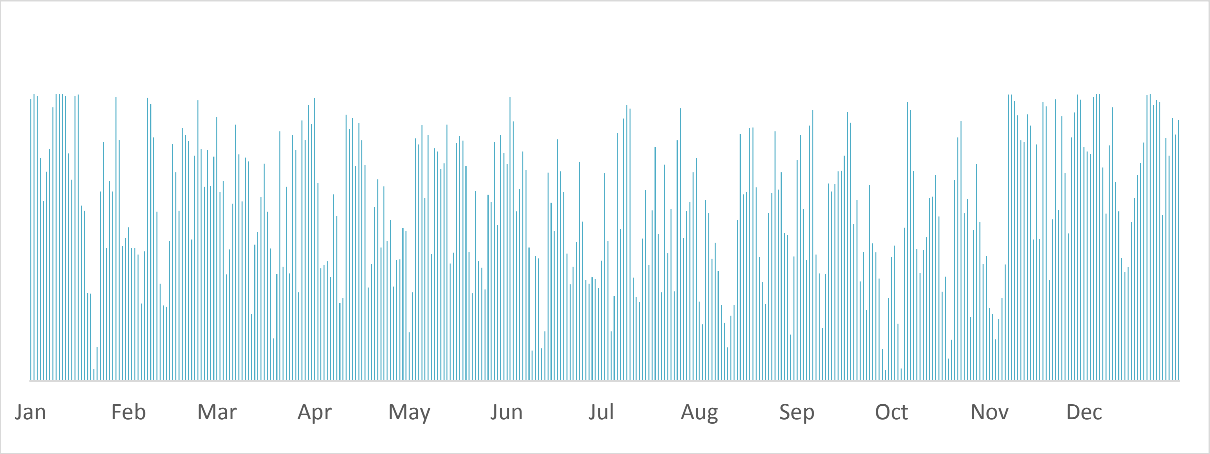

Figure 3: Wind energy production simulation for 2015 on Samsø [8]

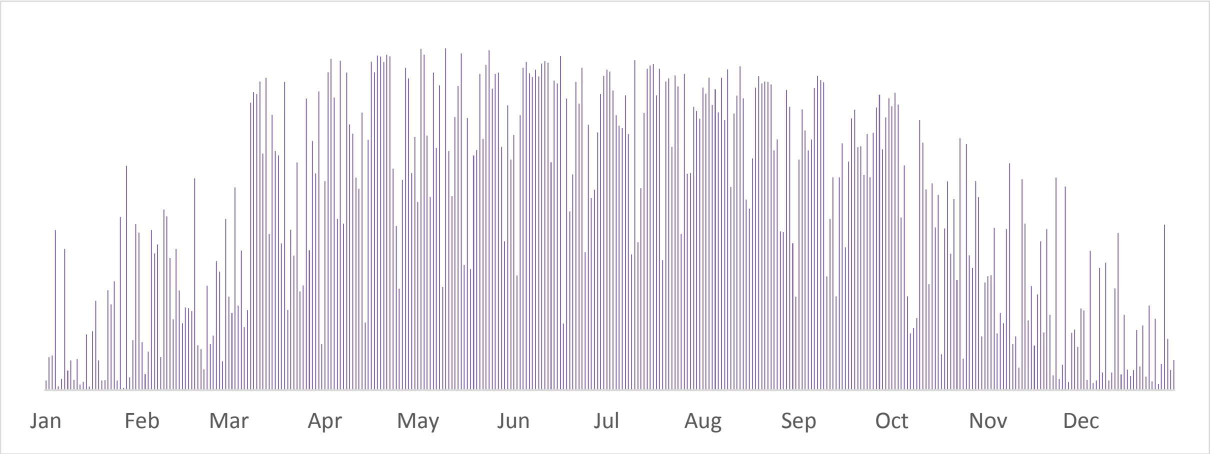

Figure 4: PV energy production simulation for 2015 on Samsø [7]

Since the hourly values of wind production make it difficult to make out a trend, Figure 5 presents the monthly shares in comparison to PV production shares. While the PV production peaks in the summer months, the wind production is related to the generally stronger winds from November until January. It should be noted that the total production of wind energy is almost 35 times as much as PV energy.

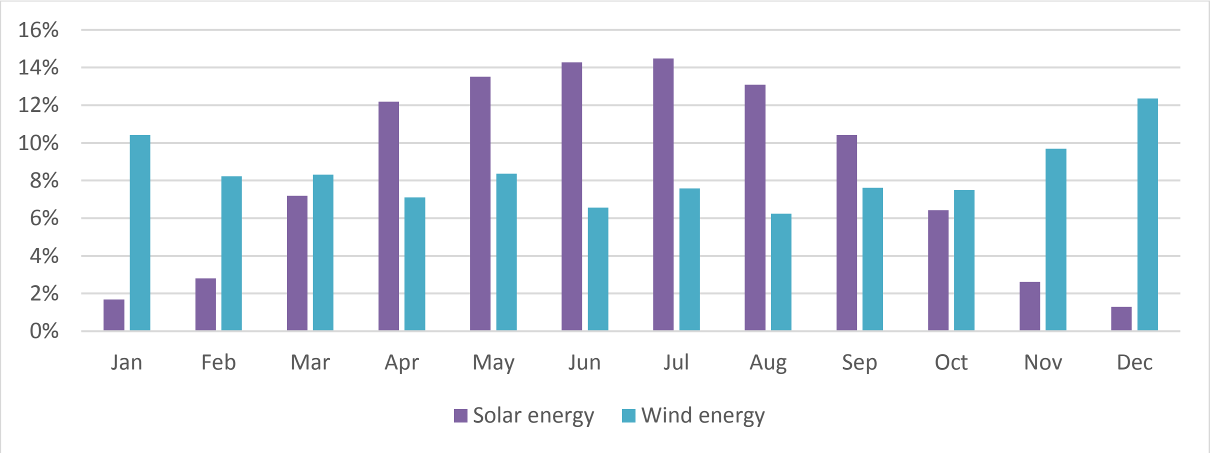

Figure 5: Monthly distribution of energy production from wind and PV for 2015 on Samsø [7], [8]

Next to the supply of electricity from wind and solar, the following shows the distribution of thermal heat production from solar radiation, depending on the outside temperatures. This influences the supply of the heating sector. Both data sets of radiation and temperature result from the Climate Forecast System Reanalysis (CFSR) weather database and are downloaded from [9]. The CFSR has hourly data with a horizontal resolution of approximately 56 km, so the typical characteristics of Samsø might not be perfectly represented, but the data is still considered sufficiently detailed. These data are then combined to calculate the resulting heat production with the energyPRO software [10]. The calculation is done for a flat plate collector at an inclination angle of 45° and results in the hourly values presented in Figure 6. To match the production from the solar collectors as listed in the energy account, a total collector area of 517 m² is required.

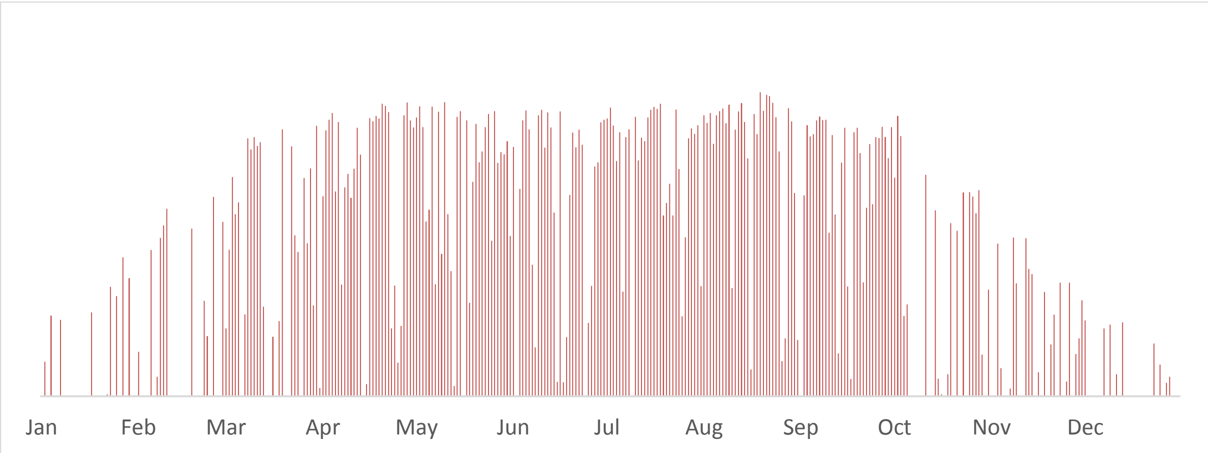

Figure 6: Solar thermal heat production for 2015 on Samsø [9]**,** [10]

3.1.2 Conversion

Table 2 presents the conversion of the supplied energy and fuels. As the concluding Sankey diagram from Figure 10 illustrates, most of the electricity production is exported via the transmission line. About 20% is directly used on the island, including a small share supplying other sectors through interconnections such as heating devices or EVs. The efficiencies listed in Table 2 are either based on the energy accounts or are standard technological efficiencies used for modelling purposes. The production column therefore present the final use after the conversion processes.

Table 2: Energy conversion on Samsø [2], [4]

	Conversion	Capacity or Annual quantity	Efficiency	Production	*Notes*
	Electric heating	3.8 GWh	avg. 155.0%[1]	5.9 GWh	[4]
	Electricity for transport	0.2 GWh	85.0%	0.17 GWh	[4]
	Biomass boiler, DH plants	7 MW	92.7%	17.0 GWh	[2], [4]
	Biomass boiler, indv.	25.8 GWh	avg. 68.5%	17.7 GWh	[4]
	Oil boiler, indv.	12.5 GWh	80.0%	10.0 GWh	[4]

[1] 3.2 GWh Heat pump with COP: 3; 2.7 GWh Electric heaters: 100%

	Gas for industry			0.4 GWh	*No conversion known* [4]
	Gas for ferries	23.0 GWh	30.0%	7.0 GWh	*Estimate* [11], [12]
	Diesel for ferries	29.4 GWh	30.0%	8.8 GWh	*Estimate* [11], [12]
	Diesel for cars	35.1 GWh	30.0%	10.5 GWh	[4]
	Petrol for cars	12.0 GWh	30.0%	3.6 GWh	[4]

The heating sector presents a variety of technologies and efficiencies: from biomass district heating to individual heaters using oil, biomass or electricity. Next to the losses through the boiler efficiency of 92.5%, the DH grid has network losses of 29.5%. While only biomass is listed as DH fuel, it actually varies from straw to woodchips and is additionally supplied by heat from solar collectors, as listed in Table 1. Most buildings that not connected to district heating use individual boilers run on biomass or oil with efficiencies between 65 and 80%. The average of 68.5% results from energy account's listing of different biomass boilers. The rest of the heat demand is supplied by electric heating devices such as heat pumps and electric heaters and is therefore using a small share of the electricity (3.8 GWh). The efficiency is an average of the standard heat pump's coefficient of performance (CoP) of 3, which translates to an efficiency of 300% and electric heaters with an efficiency of 100% [4].

Another large share of the supplied fuels goes directly to the transport sector. It mostly supplies combustion engine vehicles and two ferries running on natural gas or marine Diesel. The total sector requires 99.9 GWh of fuel. An average fuel efficiency for the transport sector of 30% is assumed, leading to a high share of PES to end up in the losses. The efficiencies result from suggested values from the energy account of 20-33% and 85% for EVs. While the fuel-based vehicles depend on fuel physically delivered to the demand side, the EVs are charged from the electricity grid. With about 25 EVs as of 2015 [13], the charging does not have a large impact on the electricity demand profile, but this might be of importance for future simulations, which could be addressed in Task 8.2 and D8.2. As of now, the EVs' charging is assumed to take place at a constant rate during the night, as people tend to charge their car when they get home from work and overnight [14]. Road transportation based on bio-fuels or LPG is neglected, as the energy account lists national averages, which cannot be applied for Samsø in this case.

3.1.3 Demand

Lastly, the different final demands on Samsø are summarised in Table 3, where all losses are taken into consideration. The losses, depending on the efficiencies listed in Table 2 add up to 90 GWh annually, as presented in Figure 10. The different final energy demands are presented in detail in the following.

Table 3: Energy demands on Samsø [4]

	Demand		*Notes*
	Electricity demand	25.5 GWh	[4]*; incl. electricity for heating*
	Heat demand	51.9 GWh	[4]*; incl. electric heat*
	Industry	0.42 GWh	[4]
	Transportation	30.1 GWh	*Calculated with* Table 2

Since the electricity production from wind turbines and PV panels exceed the demand of 25.5 GWh, excess electricity of almost 90 GWh is exported in the reference model. The remaining electricity demand is applied as specified in Figure 7 with the electricity consumption by sector. The residential sector is using most for electrical appliances including electricity-based heating systems.

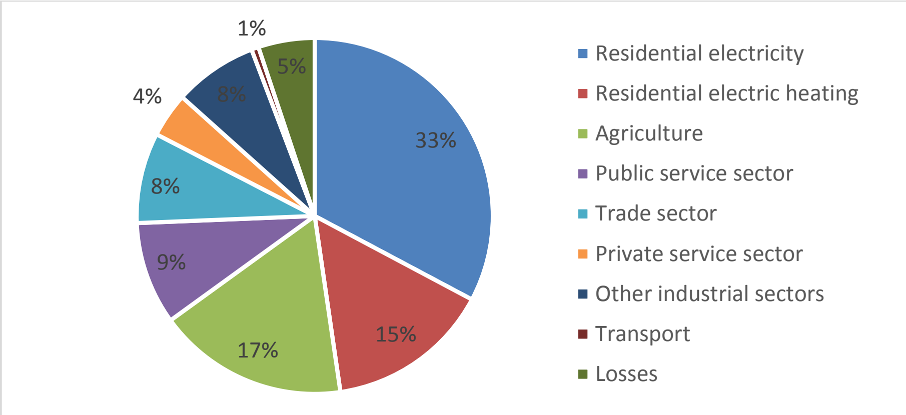

Figure 7: Electricity demand on Samsø by sectors [4]

For the EnergyPLAN simulation the electricity demand needs to be distributed by the hour. Since this data is not available, a study about typical Danish electricity demand profiles [15] is used and adapted to the energy account values. The resulting profile is shown in Figure 8. It includes the typically higher demands in the darker winter months, as also daily differences can be made out, since peak demands are lower in the weekends. While the peak demand of 4.5 MW can be identified in February, the minimum demand of 1.7 MW can be expected in the summer period during nights. When compared to 2016 electricity data, which is unfortunately incomplete, an increase of demand in the summer resulting from tourism could be made out, which cannot be made out here, but data from a specific year could also be too untypical to represent a reference model. This study profile, on the contrary, presents more average demands and is therefore well suited for modelling.

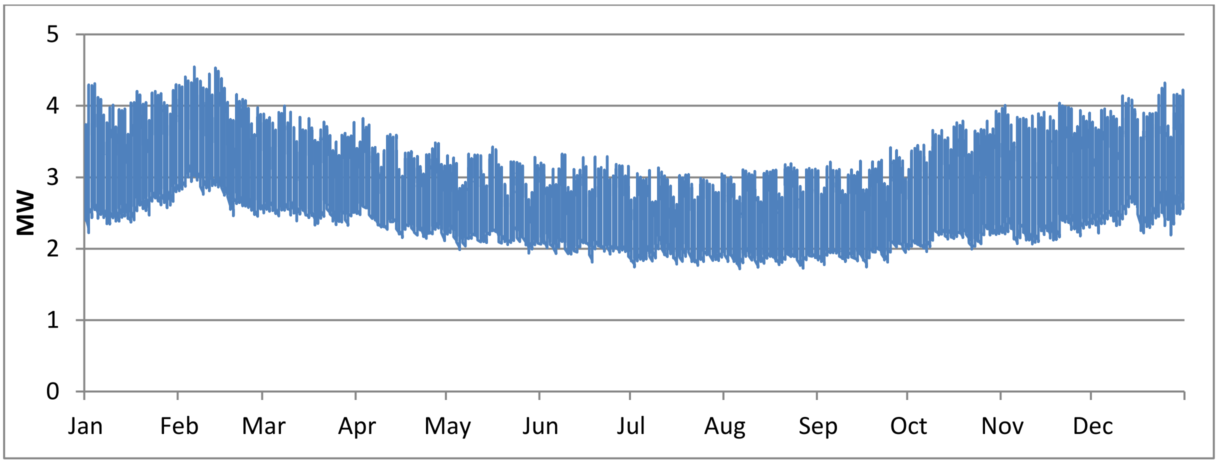

Figure 8: Electricity demand on Samsø for 2015, based on Danish study [4], [15]

Next to the electricity demand, the heat demand is needed in hourly values. The total heat demand, which is covered from mostly biomass, but also with individual oil boilers and solar thermal heat, sums up to 51.9 GWh in the reference year. The distribution is simulated based on the outside temperatures [9] for the space heating demand, as well as typical hours of hot water needs. With a typical share of 82% for space heating and 18% for hot water demand, which is based on studies, the demands are calculated for each hour [16], [17]. For the simulation of the district heating, an additional constant grid loss is added based on the energy account [4].

Figure 9 presents the modelled heat demand without the addition of grid losses, therefore, representing the heat demand distribution for all individually heated buildings, as applied in EnergyPLAN. While the heat demand in the DH grids adds up to 18 GWh annually, Figure 9 presents the total demand profile of 34 GWh, which is supplied from the individual biomass and oil boilers as well as the small share of solar collectors and the additional electric heaters and heat pumps.

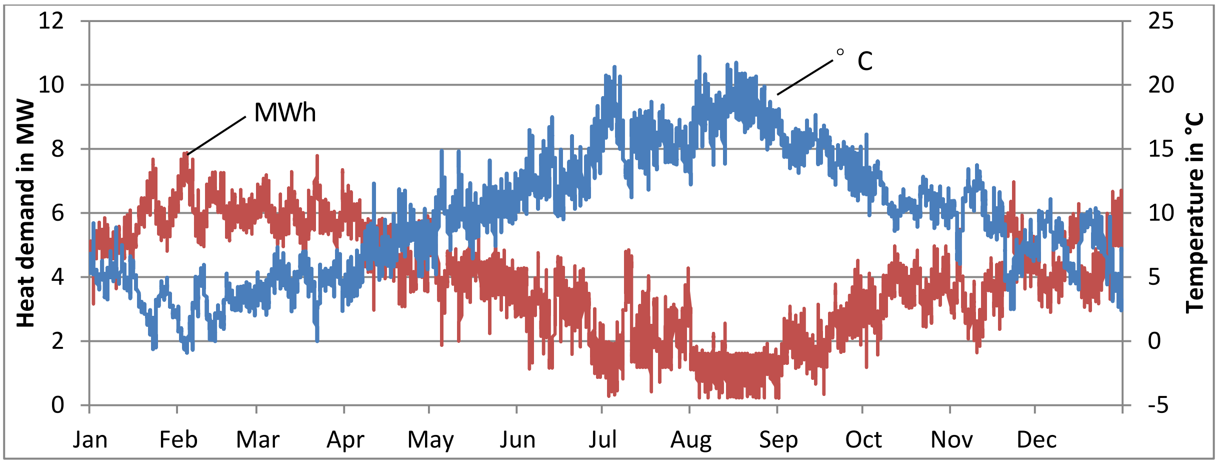

Figure 9: Temperature and resulting heat demand simulated for individually heated buildings in 2015 on Samsø [9]

For the simulation of the industry and transport demand, no distribution profile is required. As mentioned before, the transportation becomes more interesting when more EVs and biofuel-driven vehicles are used more, but as of now, the transport sector barely interacts with other sectors. A constant EV charging during the night-time is applied in this reference model.

3.1.4 Results

Besides some already presented values above, Table 4 sums up the resulting values for the reference model for Samsø as modelled with EnergyPLAN. In the Appendix, the EnergyPLAN printouts are attached, including monthly production and consumption data, as well as annual costs. The finally resulting overview of the energy system reference model is presented in a Sankey diagram in Figure 10.

Table 4: Overview of EnergyPLAN results for Samsø

	Samsø reference model
RES share of PES	60%
RES electricity production	111.6 GWh
Imported electricity	1.5 GWh
Exported electricity	87.4 GWh (78%)
Oil consumption per year	89.0 GWh
Gas consumption per year	23.4 GWh
Biomass consumption per year	52.2 GWh
CO_2 emissions per year on island	28.5 kt

The result of the reference model is presented as a Sankey diagram in Figure 10, including the various fuels supplied and the resulting final energy demands, losses or exports. Here, the different appliances of the fuels are visualized, as well as the losses in the different sectors. To simplify the presentation of the various heating technologies, they are summarized under the *Heat* node and all road and marine transportation types are combined in the *Vehicles* node. Its details are presented in the previous Sections, mainly in 3.1.2.

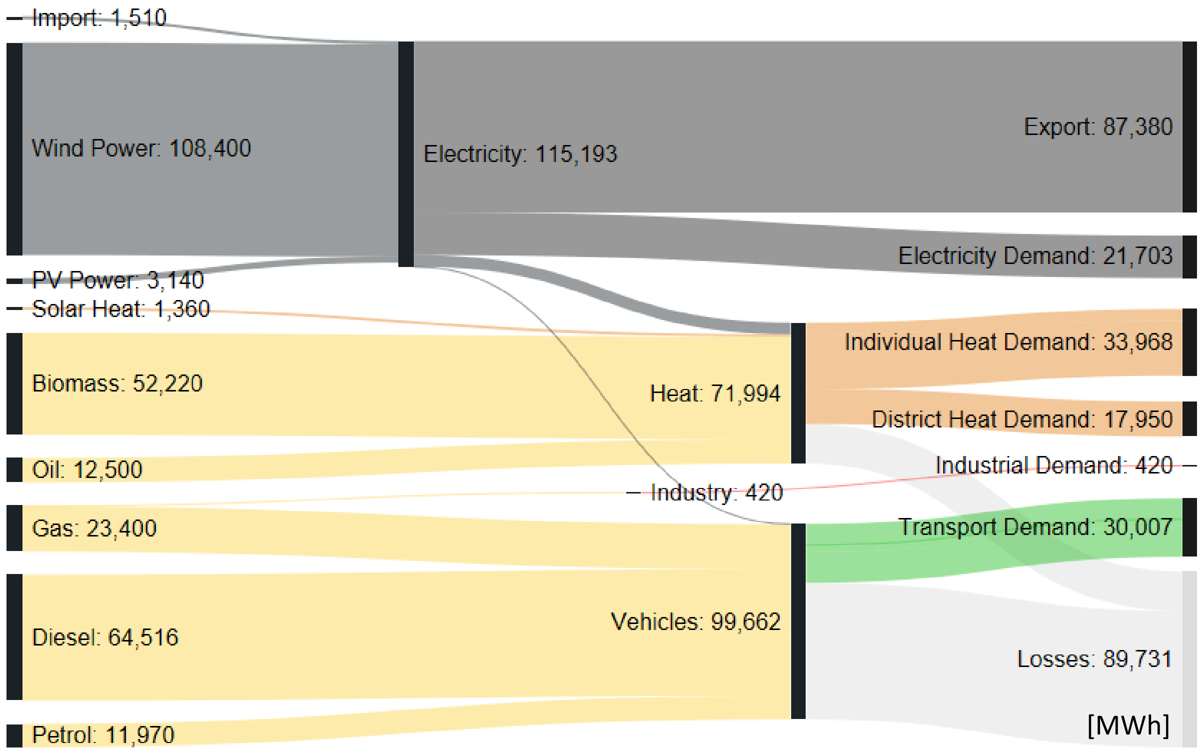

Figure 10: Sankey diagram of Samsø's reference model of the energy system for 2015

While the electricity supply is almost completely based on RES, the total energy system is supplied by RES by 60%. Additionally, wind energy is exported, namely 78% of its total production, which could be counted as replacing fossil-fuelled electricity elsewhere. In this reference model the total export is 87 GWh sustainable energy annually and the import of non-sustainable fossil fuels on the contrary is 112 GWh, of which almost half results from the ferry transportation to and from Samsø. Furthermore, while some of the biomass is harvested and provided on Samsø, like some local straw, a large extend is imported, making it also not 100% sustainable when considering the import.

A reduction of not only oil-based vehicles, but also of imported biomass for heating should be addressed for a more sustainable energy system on Samsø. Otherwise, an increase in wind energy being used in the transport sector or for heating could be addressed. A battery could furthermore support the challenges in the electricity sector to some extend by mitigating some of the fluctuations. Within the frame of the SMILE project, Samsø tries to test the integration and acceptance of a battery in combination with fluctuating energy production in a case study of the marina in the town Ballen. This will be part of the future EnergyPLAN models and Task/D8.2.

3.2 Orkney Reference Model

The 70 islands belonging to the municipality of Orkney, out of which 20 are inhabited, lie to the north of the Scottish mainland's coast. Being located within open waters on three sides, the Orkney Isles are characterized by a mild climate, which offer good opportunities for wind and ocean energy production. Within the United Kingdom and over the last 30 years, Orkney has been in the front with the development of renewable energy technologies and the generation of its energy [18].

Figure 11 shows an overview of the energy system of Orkney as of 2014, which is presenting the reference year for the energy simulation model for Orkney. Since the wave and tidal power facilities are still considered test facilities and not in commercial operation, they are not considered in the reference system. However, a large amount of wind turbines and some PV panels produce sufficient amount of electricity, which is exported to a large extent. Two transmission lines with a total capacity of 40 MW are mainly used for exporting the excess wind power production, but the limits of the Orkney distribution grid results in some curtailment of wind power production. The community is therefore focusing on solving mainly this problem within their energy system, resulting in focusing on more local use and possibly more interconnects to the Scottish mainland in the future as presented in the reference model.

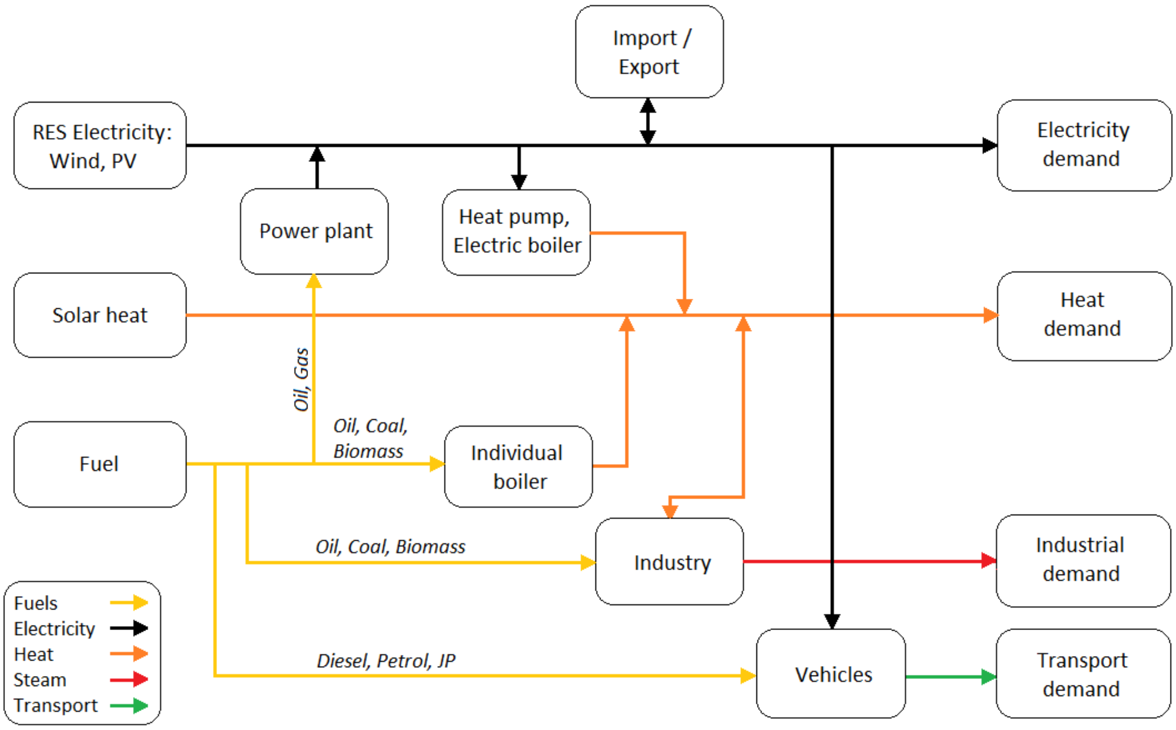

Figure 11: Overview of the energy system of Orkney

Figure 11 illustrates the current energy system set up as seen in EnergyPLAN and shows the reference energy model for Orkney. It shows supplies on the left, their application or conversion in the centre and the demands on the right. The details are presented in the following Sections. For the reference model of Orkney, the *Energy Audit 2014* [18] and local data is mainly used. For other information, national or Scottish statistics are reviewed [19]–[22]; or data is generated as presented in the following.

3.2.1 Supply

Within the SMILE project, Orkney represents the medium sized island with around 22,000 inhabitants, and energy demands which lie between Samsø and Madeira's. Section 4 presents further details for comparison between these three. With a remarkable high share of RES by British standards, the Orkney energy system is supplied with a similar amount of RES as Samsø. While wind and PV are exploited to an extent that is limited by Orkney's transmission system, oil products supply the majority of the total energy system.

An installed wind power capacity of 48.3 MW results from a high share of standard turbines, such as Enercon and Nordex with capacities up to 2.75 MW, but also from around 500 domestic-scale wind turbines [23]. The resulting modelled wind power production of 149.68 GWh for the reference year 2014 almost reaches the annual electricity demand of Orkney, but due to the fluctuation of its production, other electricity needs to be provided. Next to the fluctuation, limits in the grid connections between the Orkney Isles are a problem, causing high shares of curtailment and a limit of firm connections from turbines to the grid. In the reference model, the capacity factor of the turbines is therefore set to 0.35. For the remaining electricity demand, a small share of PV systems and the two 20 MW sea cables supply some of the additionally required electricity.

Additional fuel, as listed in Table 5, can also be used for electricity production through thermal power plants. More on this follows in Section 3.2.2 on energy conversions in Orkney. The total amount of fuel for electricity production results from the EnergyPLAN model, which simulates the production of electricity from fossil fuels when not enough wind and PV power is produced. On top of that, the fuels listed in Table 5 sum up all fuels regardless of final use. Therefore, the amount of oil also includes transportation fuels for boats (37%), Diesel cars (12%) and Petrol cars (6%), as well as direct use in the industry (29%) and individual oil-fired boilers. In addition, the amount of gas to supply the energy system of Orkney is made up of a large share for power production, as well as gas-fuelled heating systems. Both biomass and coal are used in heating and industrial demands to which more follows later in Table 6.

Table 5: The energy supply of Orkney

	Supply	Capacity/ quantity	Production	*Notes*
	Wind onshore	48.3 MW	149.7 GWh	[18], *EnergyPLAN* [1]
	PV	1.3 MW	1.2 GWh	[18], [22]
	Transmission line / Import	40 MW	10.8 GWh	[1], [18]
	Solar (thermal) collectors	150 m^2	0.05 GWh	*Estimation,* [10]
	Biomass	> 500 t	2.0 GWh	*Estimation,* [18]
	Oil (for heating and transport)	> 48 kt	598.8 GWh	*EnergyPLAN output*
	Natural Gas	> 7 kt	71.5 GWh	*EnergyPLAN output*
	Coal	> 3 kt	21.1 GWh	[18], [21]

As presented in Table 5, the total share of renewable sources in the primary energy supply reaches 17%. While the wind power production is good on Orkney, the transport and heating sector still rely on other fuels, such as oils.

For the hourly simulation in EnergyPLAN, the wind and solar productions are specified by their distribution profiles throughout the whole year with a one hour temporal resolution – here the reference year 2014. The following figures present these distribution profiles for wind power, PV power and solar thermal production. Since no measured production data is available, the distribution of the electricity production from wind and PV is modelled with a renewable energy simulation website [7], [8], resulting in Figure 12 and Figure 13. For the profile of wind power production, the turbine type Enercon E44 is used for modelling, as it is also a type common on Orkney.

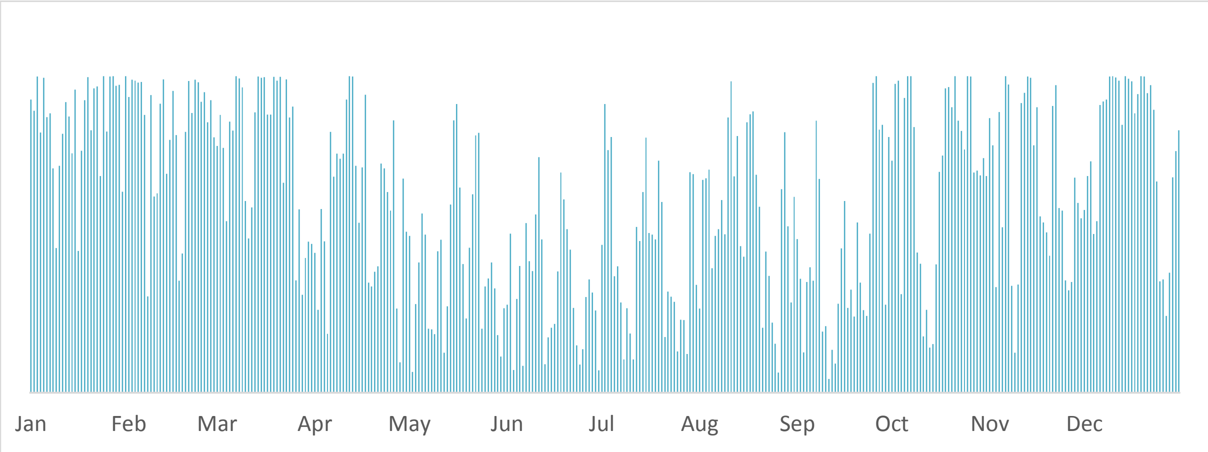

Figure 12: Wind energy production simulation for 2014 for Orkney [8]

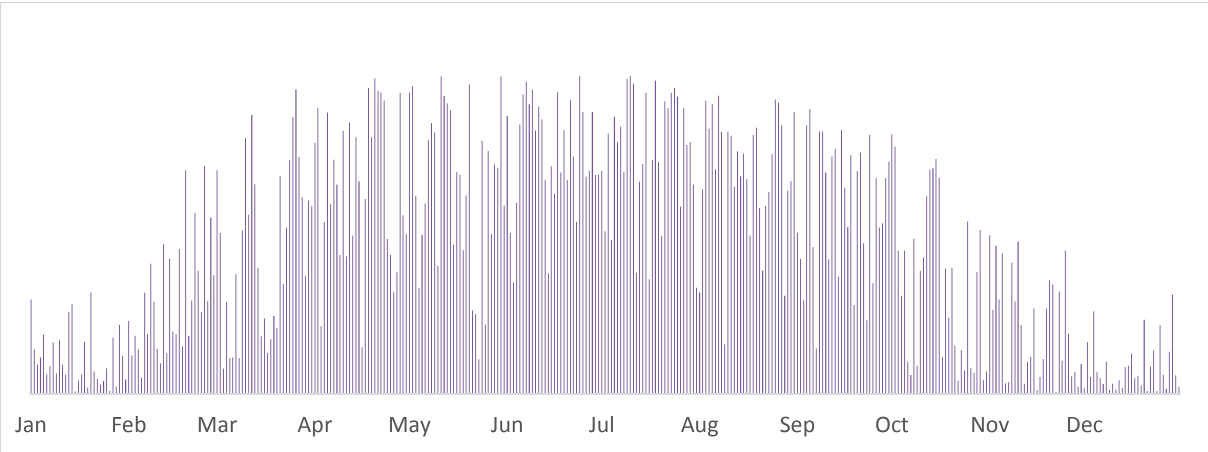

Figure 13: PV energy production simulation for 2014 on Orkney [7]

The distribution of wind and PV power production varies strongly throughout the year, as further illustrated with Figure 14. With wind production much lower in summer than in winter and with a much smaller capacity of PV, the electricity demand might not be possible to be covered with RES in some months, while other months have abundant amount of electricity from wind. It has to be kept in mind that the PV production is around 1.2 GWh annually, while wind produces 150 GWh.

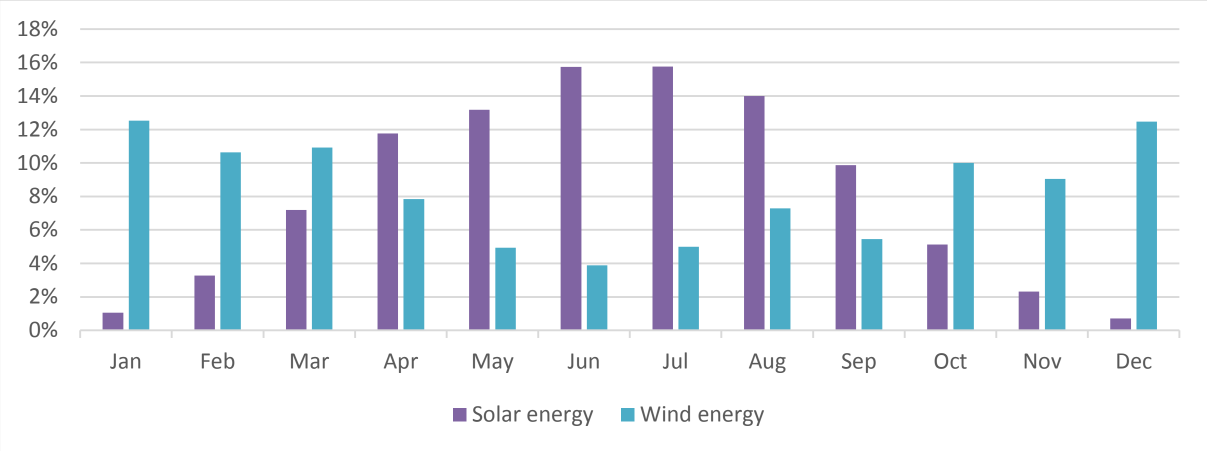

Figure 14: Monthly distribution of energy production from wind and PV for 2015 on Orkney

Solar radiation is not only used for the production of electricity through PV systems, but also to produce heat through solar collectors. Only a small number of thermal collector systems are listed in the energy audit, while the statistics for the Renewable Heat Incentive (RHI) programme lists a total number of almost 100 installed systems by the end of 2014. The RHI was initiated in April 2014 to encourage the switch to renewable heating systems in the domestic sector [24]. While the total number of installations can be extracted for Orkney, the technology types are only given for the installations in the whole of Great Britain, out of which 22% are solar thermal technology installations. In total, this would add up to about 20 solar thermal system. With an average system size of 6 m² [16] per standard unit with a couple of larger scale systems, a total of 150 m² can be assumed to be on Orkney. The heat production from standard flat plate collectors is then modelled with energyPRO, where CFSR data for radiation and temperature is applied [9], [10]. The result is an annual production of 50 MWh.

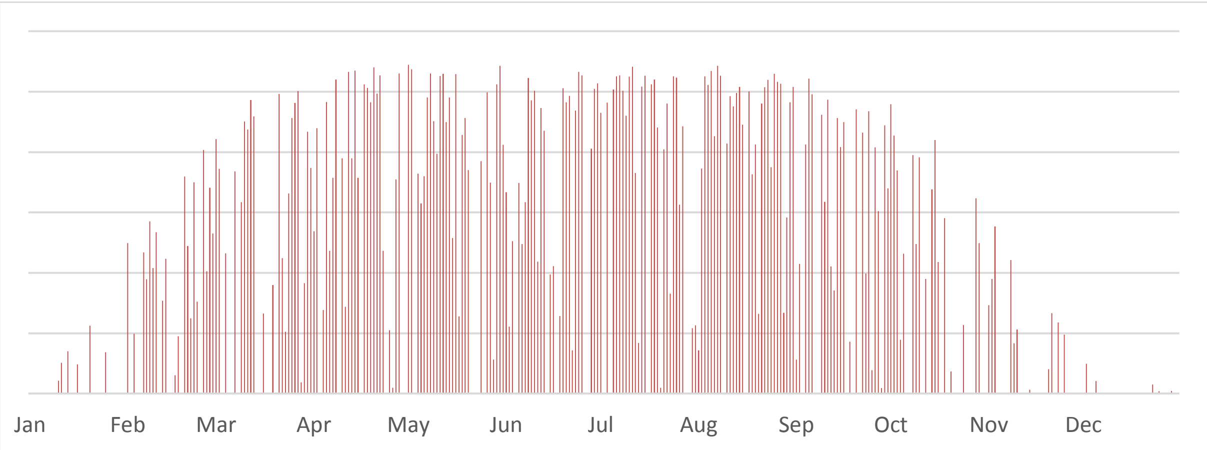

Figure 15: Solar thermal heat production for 2014 on Orkney [9], [10]

3.2.2 Conversion

The energy conversion includes fuel for electricity production via power plants and electricity converted to other final energy usages, such as heat and transport. Additionally, heating units and various vehicles need fuel for the same purposes. These processes can be seen in the Sankey diagram of Figure 19 between energy supply and energy demand and are all listed in Table 8.

As mentioned before, when the electricity production from wind and PV cannot supply the electricity demand, EnergyPLAN models power production from power plants and thereby calculates the amount of fuels needed. The power plants Kirkwall and Flotta are using fuel and producing electricity very differently. Kirkwall has a capacity of 15 MW and runs on Diesel, but ceased regular operation in the 90's and only runs for tests and back-ups. The Flotta oil terminal extracts gas for onsite heating and to run gas turbines with a 10.5 MW grid connection [18]. For both, an average efficiency of 45% is assumed. Since Kirkwall is not used for regular power supply, the reference model is not considering the plant in the energy system simulation. Also, the Flotta gas turbines are not reliable electricity suppliers, but are nonetheless considered to feed to the grid with all the turbines available when demanded in the reference model. Its production of 42 GWh would otherwise be imported to Orkney, but no information is available on that part. For the reference model including the Flotta terminal, an import through the sea cable of 10.8 GWh is still required.

The Energy Audit lists imports of around 40 GWh in 2013 with a decreasing trend due to the increase in RES. A total of 93 GWh gas is therefore simulated to supply Orkney with electricity, when wind and PV are insufficient. Regarding the electricity sector, some (16%) of this electricity production is used in other energy sectors, namely heat production and transportation.

The high share of electric heating devices results from a Scottish census, presenting a share of 41% of heating devices in Orkney municipality to be electric [25], while the total heat demand of 200 GWh annually derives from the Scotland heat map [26]. The other heating devices are fuelled with oil, coal and some biomass as stated in the statistics for residual fuel consumption, which refers to fuel commonly used for heating purposes [21]. The amount of biomass includes the use for industrial purposes, including whisky-making processes, where end demands are considered to be in the form of heating. The statistics, however, seem to deviate from the experience of locals regarding the amounts of fuel. The listed biomass of 88 GWh is instead estimated to be around 2 GWh. This estimation results from the peat amount and known wood pellets used on Orkney, plus an assumption of unknown delivery and the UHI's wood crop testing [17]. Also the coal listed in the statistics seem to be overestimated and the average known delivery to by Orkney Council is considered more trustworthy. The amount of gas for heating use is not listed in the residual fuel statistic, but only stated in the Energy Audit. This review results in oil being the most common heating fuel, presenting a large potential for improvements to reduce the use of fossil fuels and perhaps increase the use of locally produced electricity with the implementation of electric heating alternatives.

The heat demands result in a total of 124 GWh with a similar share of electricity based heat, but otherwise rather low compared to the heat map, so either the Scottish heat map has faults or this indicates data gaps in the reference model of Orkney. All efficiencies from boilers are taken from standard technology data.

Table 6: Energy conversion on Orkney

	Conversion	Capacity/ quantity	Efficiency	Production	*Notes*
	Electric heating	15.3 GWh	Avg. 354%[2]	54.1 GWh	[18], [25], [26]
	Electricity for transport	50 EVs		0.1 GWh	[18]
	Oil heater, domestic	76.0 GWh	80%	60.8 GWh	[21]
	Biomass heater, various	2.0 GWh	70%	1.4 GWh	*Estimate* [18]

[2] Energy Audit lists various heat pumps in Orkney with efficiencies of 245-460% (COP 2.45-4.6) [18]

	Gas heater, domestic	1.4 GWh	90%	1.2 GWh	[18]
	Coal heater, domestic	8.5 GWh	70%	6.0 GWh	[18]
	Oil for power plant (back-up)	0 GWh	45%	0 GWh	[18]
	Gas for power plant	93.1 GWh	45%	41.9 GWh	*EnergyPLAN output*
	Oil for industry			176.8 GWh	*No conversion known* [21]
	Coal for industry			12.6 GWh	*No conversion known* [21]
	Diesel for boats (Marine oil)	228.0 GWh	30%	68.4 GWh	[18]
	Diesel for cars	75.1 GWh	30%	22.5 GWh	[19]
	Petrol for cars	36.1 GWh	30%	10.9 GWh	[19]
	Jet Fuel for airplanes	6.9 GWh	30%	2.0 GWh	[18]

Further listed in Table 6 are the fuels in the industry and transport sector. Some oil and coal are listed as in the residual fuel consumption statistics for industrial purposes [21], while gas might be used internally in the Flotta power plant, which is neglected in this model. The road transport values, on the other hand, result from road transport statistics for diesel and petrol cars [19] or from the Audit. The highest share of fuels can be made out in the marine transport, including mainland and inter-island ferries, small fishing boats and other vessels, while air transport forms the smallest consumer with a few mainland and inter-island connections. Finally, EV demand is calculated by taking a number of 50 vehicles with 1.5 MWh annual consumption into account. These are supplied with electricity currently modelled with a simplified dump charge from 20:00 – 7:59.

3.2.3 Demand

The electricity production and supplied fuels result in the energy demands on Orkney after the conversion to the final energy type. This is presented in Table 7.

Table 7: Energy demands on Orkney

	Demand		*Notes*
	Electricity demand	154.7 GWh	*Incl. heating*
	Heat demand	123.5 GWh	*Incl. electric heat*
	Industry	189.8 GWh	
	Transportation	103.9 GWh	*Calculated with* Table 6

The total electricity demand of 154.7 GWh annually, based on [20], is generally split into non-domestic and domestic uses, which can be further split into domestic electricity, heating and transport. The absolute numbers are 73 GWh, 57 GWh, 25 GWh and 0.1 GWh for the reference year.

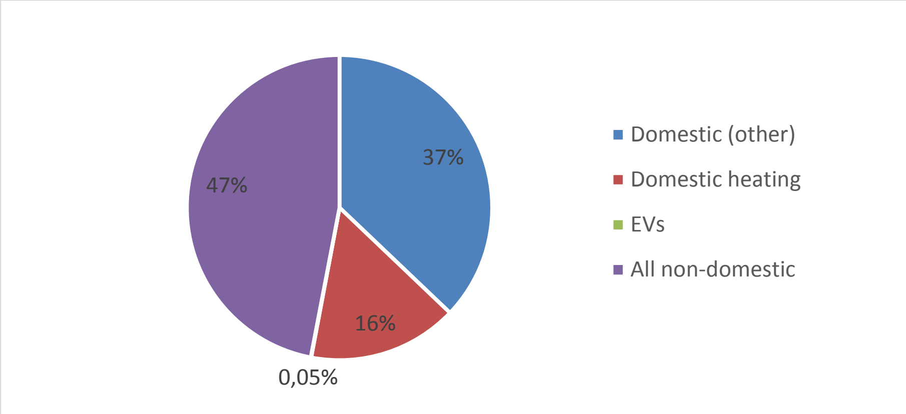

Figure 16: Electricity demand shares on Orkney

Heat pumps and electric heaters are presented in both the electricity demand and the final total heat demand in Table 7. The total final electricity demand without the share for heating is 130.0 GWh annually. The distribution for the modelling in EnergyPLAN is shown in Figure 17, which is based on the European Network of electricity TSOs [27] for Great Britain in 2014. Multiplied by 130 GWh, the peak demand reaches almost 23 MW and the minimum is 8 MW, while the DNO's ANM modelling is based on winter peak of 36MW and summer low of 7MW, hinting that the national data presents a more flattened curve that would be realistically on Orkney. However, the demand for electric vehicles and electric heating is not included in this distribution and theoretically added on top of that getting closer to the DNO's peak value, but follows the heating distribution profile, which is introduced below.

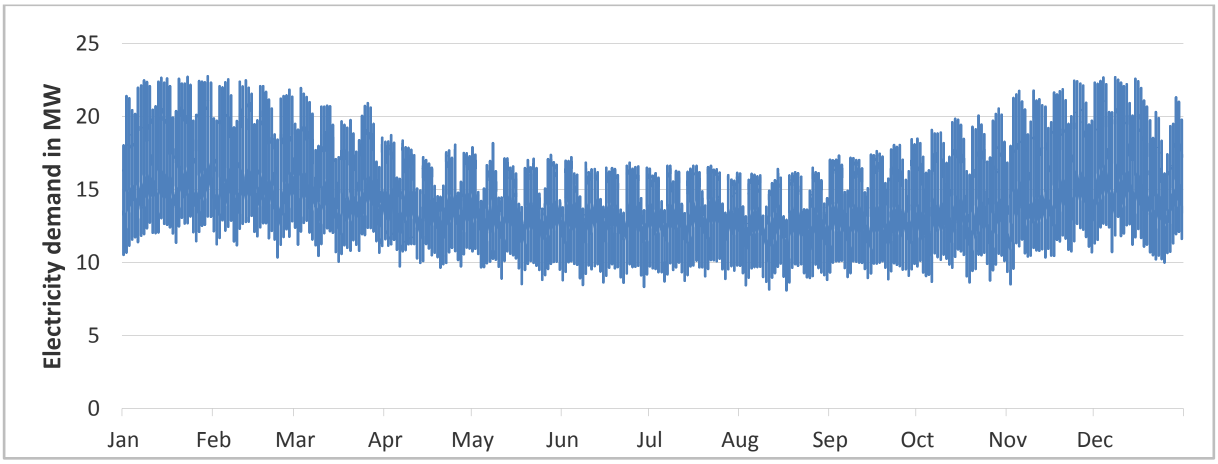

Figure 17: Electricity demand for 2014 on Orkney [27]

The various fuels for heating, as well as electricity for heating, follows the hourly distribution of heating demands. This is simulated with the temperatures for 2014 from a numeric weather model [9] and typical distributions. Space heating, which is assumed to take up 82% of the total heat demand, is modelled to be required when the temperature is below 15°C. Domestic hot water takes up the remaining 18% and follows typical daily profiles for weekdays and holidays, including e.g. peaks around noon. The resulting distribution is shown in Figure 18.

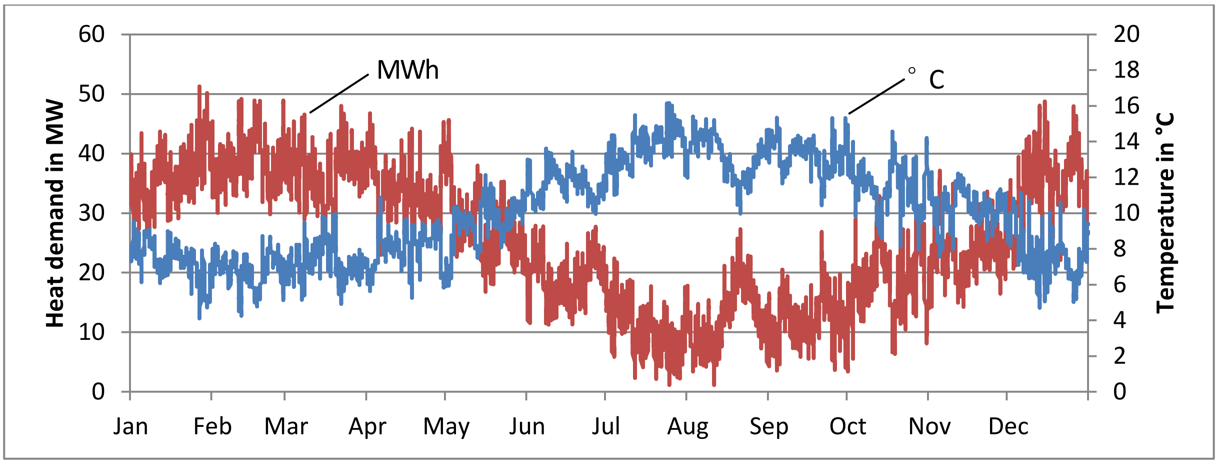

Figure 18: Temperature and resulting heat demand simulation for 2014 on Orkney

The final demands in the industry sector are not further evaluated, both due to the limited amount of data on the further usages, but also since it is not modelled in detail with EnergyPLAN. The industrial demand is supplied mostly with oils (93%) and coal (6%).

Transportation in Orkney includes a large share of marine vessels, which represent 64% of the fuel demand in the transport sector, while 2% relates to air transportation, leaving the remaining fuel needed on roads. The distribution of fossil-fuelled vehicles is not further discussed as it is of not relevance to the other sectors. On the other hand, the charging of electric vehicles can be of importance due to the electricity required and due to the competition with other electricity demands, having an influence on demand peaks etc. As of now, the charging is most likely done randomly and not much information is available, leading to an assumed demand during the night, as their users are likely to charge their EVs when they get home from work and daily routines. A constant charging is therefore assumed for the night from 20.00 until 7.59 in the morning.

3.2.4 Results

This Section presents the final resulting overview of the EnergyPLAN reference model for the Orkney Isles. While the resulting EnergyPLAN printout is attached in the appendix, the main results can also be viewed in Table 6. All energy supply, conversion and demands, as explained in detail before, are furthermore presented in a Sankey diagram, see Figure 19.

Table 8: Overview of EnergyPLAN results for Orkney

	Orkney reference model
RES share of PES	17%
RES electricity production	150.9 GWh
Imported electricity	10.8 GWh
Exported electricity	48.9 GWh
Coal consumption per year	21.1 GWh
Oil consumption per year	598.8 GWh
Gas consumption per year	94.5 GWh
Biomass consumption per year	2.0 GWh
CO_2 emissions per year	186.2 kt

Figure 19 shows the resulting reference model as an energy system in detail, including supply of locally generated electricity and (mainly) imported fuels with the resulting demands or losses. As the previous

Sections clarified, the *Heat* node includes various heating technologies, while the *Vehicle* node includes the large share of marine vessels, as well as cars and planes. Compared to Samsø or Madeira, Orkney has a large share of final energy demand in the industrial sector.

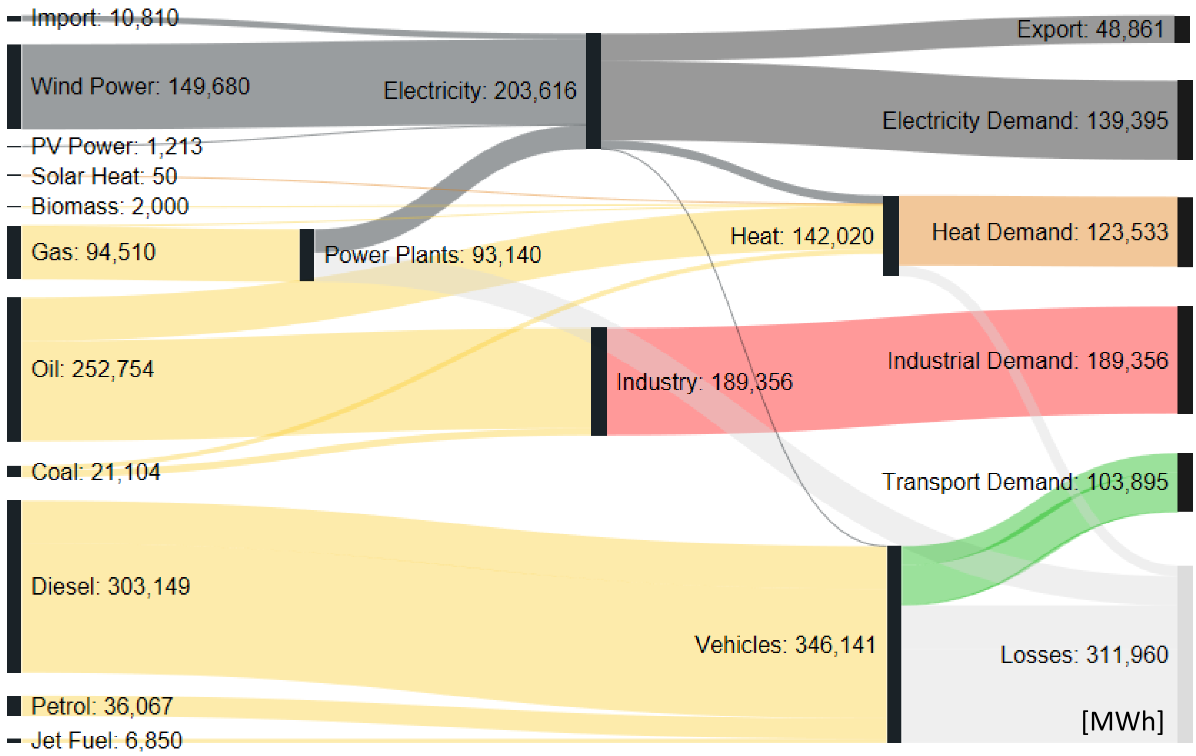

Figure 19: Sankey diagram of Orkney's reference model of the energy system for 2014

While the electricity sector is mainly supplied by locally produced electricity, the heating sector still relies a lot on fossil fuels, even though Orkney has a an electric heating share above the average. But the fuels needed in the transport and industrial sector reduce the overall share of RES to the listed 17%.

Within the SMILE project, Orkney aims at improvements in the domestic heat and industrial load management, partially addressing the high amounts of oils currently used. Furthermore, the high amount of wind production, which exceeds the demand and is often curtailed, is planned to be used more locally through electrolysers and the support of EV usage. This will be addressed in the upcoming Task and D8.2, but has its origin in the reference model presented here.

3.3 Madeira Reference Model

With a distance of several hundred kilometres to the next mainland, Madeira lies isolated both from the lands and from the electricity grids of Europe and Africa. In comparison to Samsø and Orkney, it therefore presents the only true island system, being independent in every way, e.g. also incinerating its produced waste to the best extent possible. Further differentiating it from most other European areas, Madeira has the typical characteristics of a southern Mediterranean climate with high solar radiation and demands including a cooling demand rather than a heating demand.

After a brief introduction to Madeira's energy system, its details are presented in the following Sections. With no transmission line connecting Madeira to a larger electricity grid, it produces all the electricity needed locally, mostly relying on the support of thermal power plants and with a large share of hydro power, which is very different to Samsø and Orkney. Additionally, Madeira offers great conditions for PV usage, but puts a limit on its injection to the grid due to difficulties with the grid frequency. With a planned increase in EVs, the frequency stability issue puts further strain on the distribution grid and security of supply.

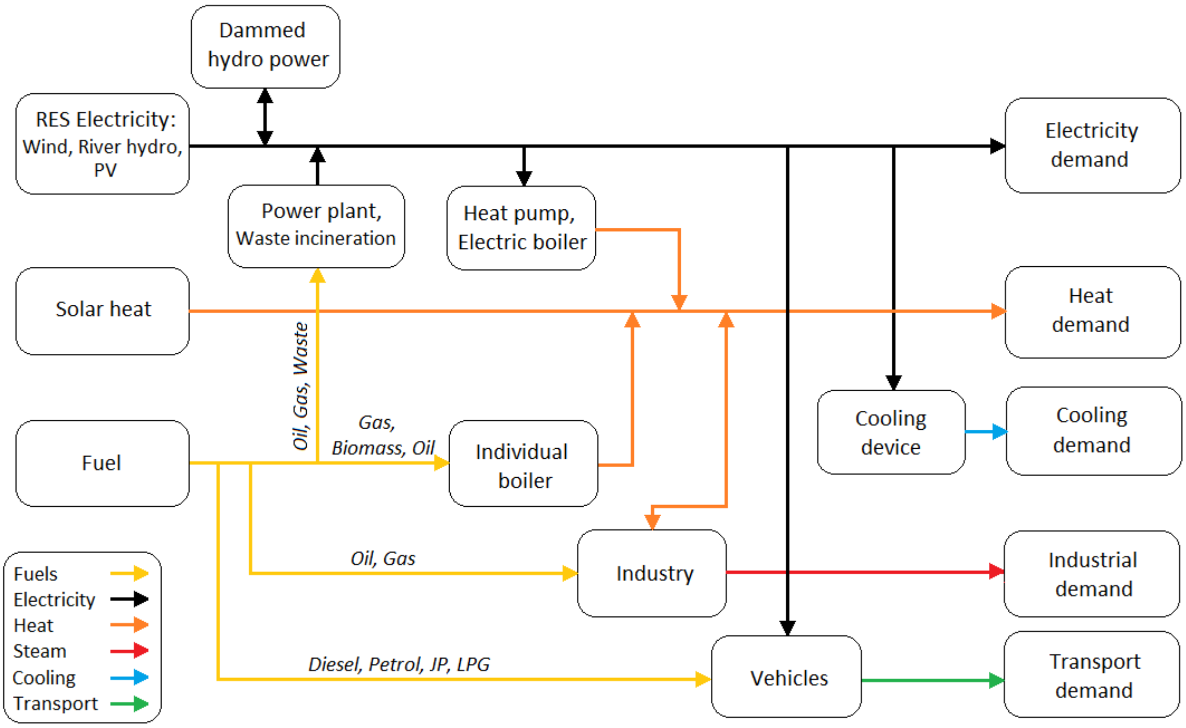

Figure 20: Overview of the energy system of Madeira

The reference model is illustrated in Figure 20, showing an overview of the energy system from supply to demand. It takes the energy supply from its sources and fuels into account, as well as the conversion types and characteristics and the final energy demand that is to be met in the various sectors. With a study of the previous three years in regards to energy production, but also weather conditions, the year 2014 was selected to use as reference year due to more average precipitation[3] and its influence on the energy system on Madeira.

[3] 480 mm of rain in Funchal for 2014; 300 mm in 2015; 625 in 2006-2015

Through the close cooperation with EEM on Madeira most data was easily accessible, for example through the 15-minutes production data files [28]. Further use of the local energy balance for 2014 by Região Autónoma da Madeira (RAM) supported this task greatly [29], as well as the local statistic bank [30]. The resulting details are presented in the following Sections, divided into supply, conversion and demand, as well as the resulting Section with the overview of the reference energy model for Madeira, including a complete Sankey diagram in Figure 31.

3.3.1 Supply

With a population of around 250.000 Madeira represents the largest population and island within the SMILE project. However, the production of renewable energy and the energy demands are not necessarily as big as to be expected in comparison to Samsø and Orkney. The demands are to a large extend covered by fossil fuels, but also a variety of RES, as D4.1 already presented:

"The electric grid in Madeira island is fed by five sources of energy, namely: hydro, wind, photovoltaic, solid waste incineration, and thermal energy from burning fossil fuels like diesel and natural gas.
(…) the electric energy production in Madeira island is guaranteed by two thermal plants, 10 hydro plants, eight wind farms, one solid waste plant, three solar farms with 7 MW, 2 MW and 6 MW respectively, and 770 distributed micro- and mini-producers, with full injection to the grid." [31]

In the following, the energy system is presented for the purpose of modelling a reference energy system, where all known supplying fuels and technologies are considered to the best extent possible.

The thermal power plants have a combined capacity of private and EEM plants of 203 MW, run mostly on fuel oil or gas, and produce most of the electricity needed on Madeira. Their total production varied from 590 to 650 GWh in the recent years [30] and within the reference model its production is modelled to be 600 GWh with a fuel supply of 1219 GWh fuel oil and 244 GWh gas for 2014, as simulated with EnergyPLAN. The energy conversion is further discussed in the next Section.

Hydro power plants form the second largest production group with 24 MW hydro power classified as dammed hydro and another 26.7 MW as river hydro plants – a total of 95.3 GWh produced in 2014. Being classified as dammed hydro enables EnergyPLAN to simulate a different operation for these depending on its pump and turbine capacities, while river hydro depends on the precipitation. Strictly speaking, Madeira has neither dams nor rivers, but these EnergyPLAN modelling functions best illustrate the hydro power production on Madeira. The hydro power station considered for the dammed hydro modelling is the Socorridos plant, which has also 11.25 MW for hydroelectric pumping.

The wind farms have a total capacity of 45.11 MW and PV solar farms with individual PV systems add up to 19.08 MW. Finally, the annual waste of more than 100,000 t produces electricity through incineration. The waste production "for treatment in the solid waste treatment plant" from 2011-2015 was on average 117 kt [30]. The supplies of the energy system are listed in Table 9: The energy supply on Madeira.

Table 9: The energy supply on Madeira

	Supply	Capacity/ quantity	Production	*Notes*
	River Hydro	26.7 MW	64.5 GWh	*Private and EEM's hydro power plants* [28][29]
	Dammed Hydro	24.0 MW	30.8 GWh	*Socorridos power plant* [29]
	Wind	45.1 MW	85.9 GWh	[28][29]
	PV	19.1 MW	25.0 GWh	[28][29]
	Solar (thermal) collectors	App. 30,000 m²	22.3 GWh	[32]
	Waste	8 MW/108 kt	140.6 GWh	[30][32]
	Biomass	> 6.6 kt	32.4 GWh	[32]
	Oils	> 235 kt	2910.3 GWh	*EnergyPLAN output*
	Natural Gas, LPG	> 40 kt	503.3 GWh	*EnergyPLAN output*

Table 9 presents next to the RES also the fossil fuels as part of the primary energy supply (PES). Next to the RES for electricity production, solar radiation is further used for heat production. Other heating fuels are the biomass, gas and a minor share of the oils. 50% of the oil are otherwise needed in the transport sector, for which Section 3.3.2 presents details. In total, 7% of the PES is based on renewable sources and that changes to 11% if waste is considered a RES. The electricity production, however, is made up by 29% of renewable sources.

In regards to the temporal distribution of the supply, the profiles for wind, PV and solar thermal are presented here, while the profiles of hydro and waste power are presented in the Section 3.3.2, since these production units are not strictly linked to the hourly amount of rainwater and waste. For the EnergyPLAN simulations hourly values are required and, therefore, the 15-minutes values from the production dataset are adapted to hourly ones and result in the Figure 21-Figure 23 and Figure 25-Figure 27.

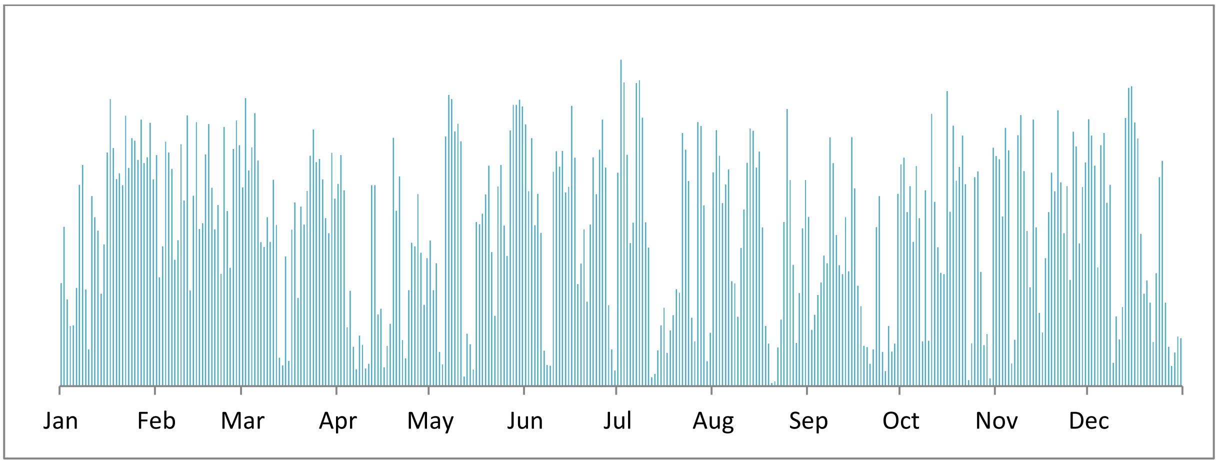

Figure 21: Wind production simulation on Madeira for 2014 [28]

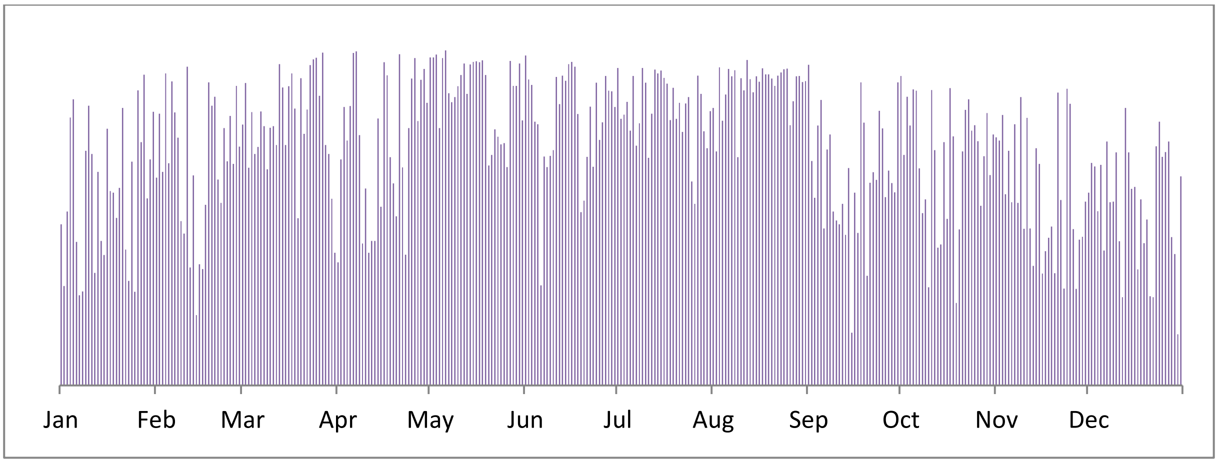

Figure 22: PV production simulation on Madeira for 2014 [28]

For clarification, the hourly values of wind and PV power production are presented in monthly values in Figure 23. As to be assumed, the PV production peaks in the summer, however, the profile is not as evenly distributed as e.g. on Samsø. Also the wind production cannot be clearly assigned to a season, but in 2014, the highest production were in the first months of the year.

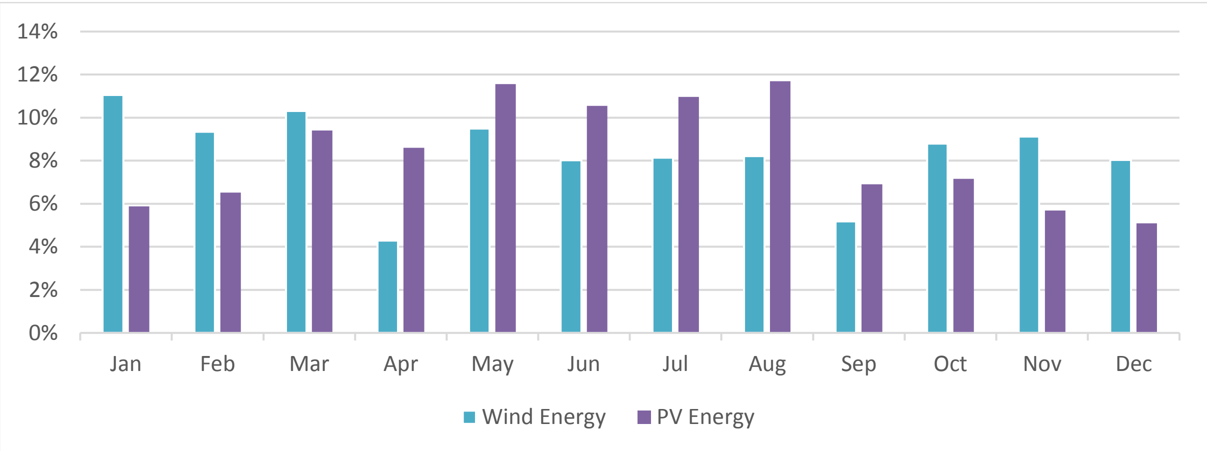

Figure 23: Monthly distribution of energy production from wind and PV for 2014 on Madeira [28]

Solar radiation is also used for the production of hot water, which is used privately in households on Madeira. The listed total production of 22.3 GWh is distributed as shown in Figure 24. The hourly production of hot water with solar collectors is simulated with energyPRO and with the temperature and radiation data of 2015 [9], [10]. The inclination for the simulation is 30°, enabling heat production in all seasons to the best extend. A lower inclination would result in higher summer peaks, but barely any production in winter, while a higher inclination reduces the summer production a lot. The energyPRO simulation suggests a total collector surface of around 30,000 m² to be used on Madeira to reach the total production of 22.3 GWh.

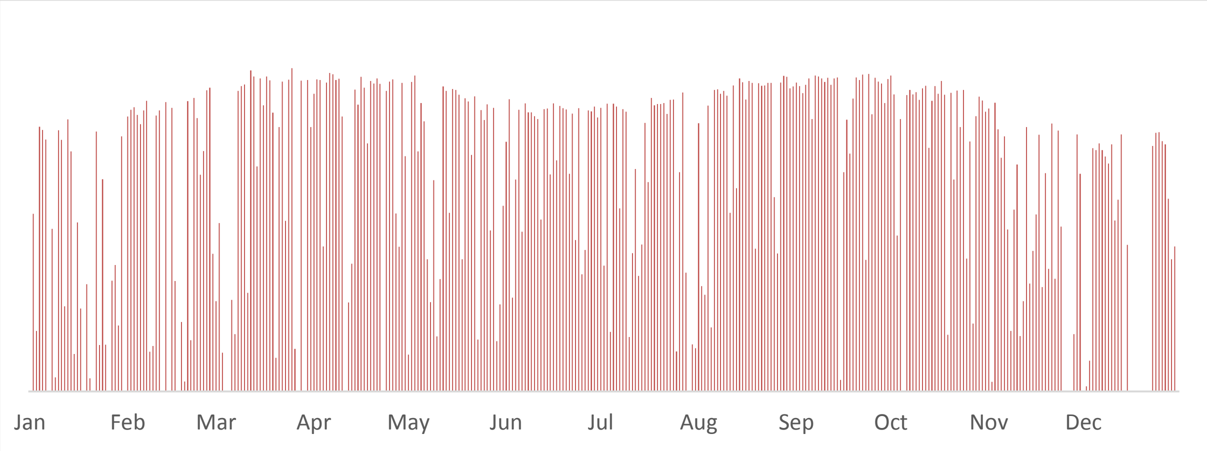

Figure 24: Solar thermal heat production for 2014 on Madeira [9], [10]

3.3.2 Conversion

From the listed primary energy supply and fuel above, the following goes into detail with the resulting energy conversions. A large share of both the fuel oil and some of the gas is used for power production in thermal power plants on Madeira. The thermal power plants' total capacity of 203 MW results in an annual electricity production of around 600 GWh in the reference year 2014. The EEM plants are running on fuel oil and gas in a capacity distribution of 3:1 and the privately owned plants only on fuel oil [33]. The fuel distributions for the power plants are therefore set to 5:1 for fuel oil and gas and are modelled to operate within EnergyPLAN for the hours when there is not sufficient electricity production from the other production units to fulfil the hourly demand.

The other electricity and fuel conversion processes are listed next to the thermal power plants specifications in Table 10. Most data originate from Madeira's energy balance [32], while efficiencies are standard values for the respective technologies. Regarding the electricity's use for other sectors, the information is limited. While only about 50 electric cars were assumed being on Madeira in 2014, the amount of electricity used is also assumed with average values per car based on the "Electric Mobility in RAM" [29]. The amount of electricity used for the final energy sector of heating or cooling is further difficult, since the final use of electricity cannot be distinguished in these terms [33]. The final energy demands are listed to some extent in Section 3.3.3.

Table 10: Energy conversion on Madeira

	Conversion	Capacity/ quantity	Efficiency	Production	*Notes*
	Thermal power plants	203.04 MW	41%	599.7 GWh	[28], [29]
	Waste incineration	140.6 GWh	23.4%	32.9 GWh	*Energy balance 2014* [32]
	Electricity for transport	50 EVs	100%	0.1 GWh	[29]
	Electric heating/cooling	?	?	?	*Incl. in total consumption*
	Biomass boiler	32.4 GWh	70.0%	22.7 GWh	[32]
	Oil boiler	12.0 MWh	80.0%	10.0 MWh	[32]
	Gas boiler	154.3 GWh	90.0%	138.9 GWh	[32]
	Oil for power plant	1219.0 GWh	41.0%	499.8 GWh	*EnergyPLAN* [1], *EEM* [33]
	Oil for industry			180.4 GWh	*No conversion known* [32]
	Diesel for cars	877.9 GWh	30.0%	263.4 GWh	[32]
	Petrol for cars	372.1 GWh	30.0%	111.6 GWh	[32]
	Jet fuel for airplanes	260.8 GWh	30.0%	78.3 GWh	[32]

	Gas for power plant	243.8 GWh	41.0%	100.0 GWh	[1], [33]
	Gas for industry			104.7 GWh	*No conversion known* [32]
	LPG for cars	0.5 GWh	38.0%	0.2 GWh	[32]
	Industry to industrial heat			9.8 GWh	[32]

The fuels listed for heating in Table 10 are listed as "final consumption" in the household sector and are therefore assumed to account for heating. Besides the fuels used in the thermal power plants, the remaining ones listed are supplying industry and the transport sector [32]. The heat production of 9.8 GWh results from the Energy Balance's section on heat from cogeneration. This is most likely sold from the AIE, a company who owns the private thermal power plants, to customers, such as laundry or food production businesses [33] Therefore, this is considered an industrial DH demand supplied by CHP in the reference model.

Going back to the electricity production from hydro and waste power plants. With 108 kt of waste and 480 mm of measured precipitation in 2014 [30], the distribution profiles are presented below in Figure 25 and Figure 26. As mentioned before, both the waste and also the water can be stored and its electricity production therefore managed to a certain extent. The dammed hydro power plants can store some of the water and produce electricity somewhat flexible, but hydro power is otherwise mostly limited by the precipitation on Madeira. However, precipitation varies from year to year, which might be of importance to consider for future energy system simulations. Normally, future energy system models would build upon this reference model, so the applied profiles need to be considered.

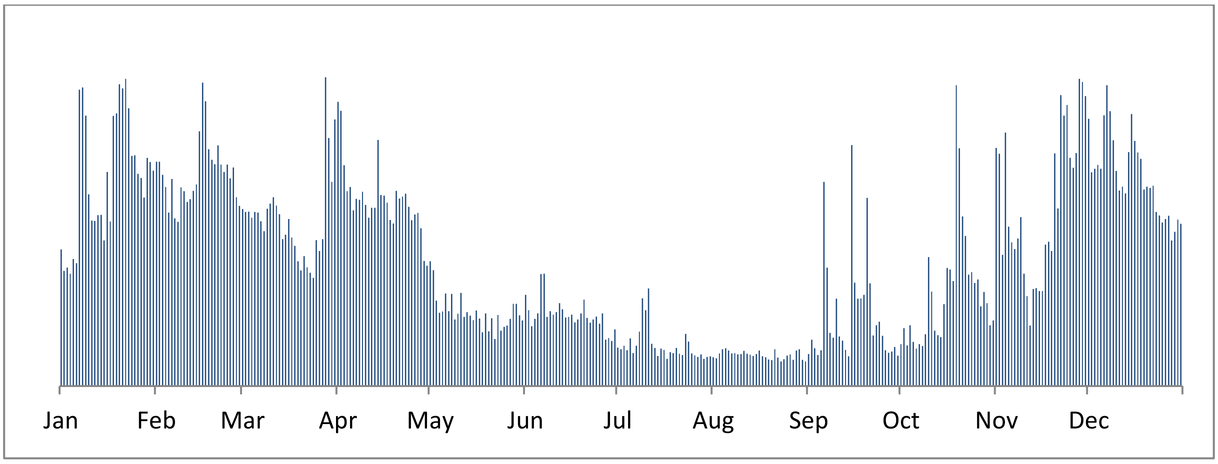

Figure 25: Hydro power production profile for river and dammed hydro in 2014 on Madeira [28]

The waste incineration plant relies on the waste production of the inhabitants and visitors, but can operate to some extent according to the requirements of the electricity grid and the incineration plant. Therefore, the following distribution profile also shows reduced operation in some periods of January to March and a complete shut-off in the autumn, as maintenance is usually done around November [33].

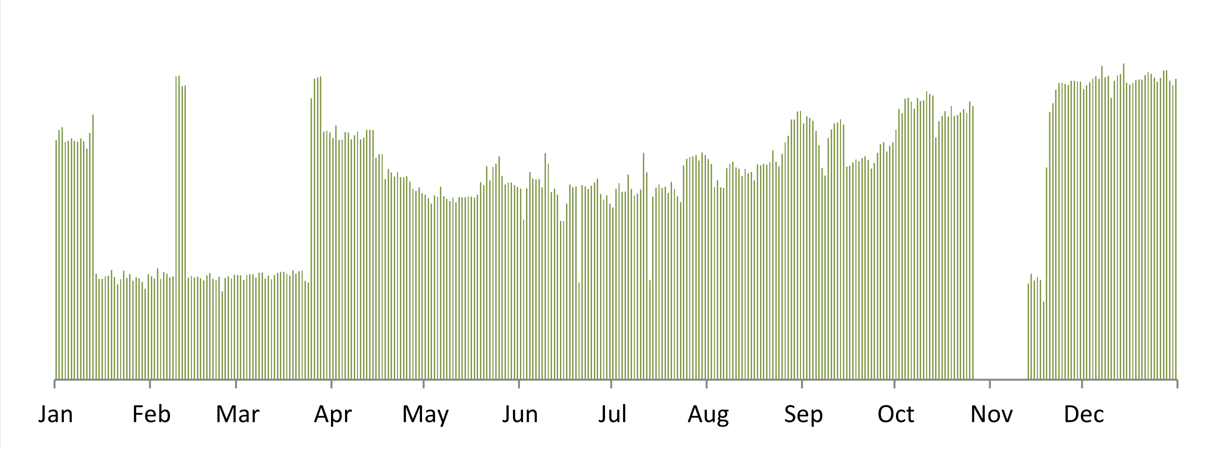

Figure 26: Waste incineration profile in 2014 on Madeira [28]

A comparison of monthly production in hydro and waste power production can be seen in Figure 27. Whereas the wind and PV power production is strictly limited to the wind and solar resources, the power from hydro and waste can be managed and operated to a certain flexibility. However, the thermal power plants need to operate constantly and produce between 25 and 120 MW with generally higher production in late summer and autumn, possible linked to the reduced wind and hydro power production during this period. The distribution profile for the thermal power plants is not required for the EnergyPLAN simulation, since EnergyPLAN calculates the remaining productions after the demands are supplied with the renewable electricity resources and mandatory operations.

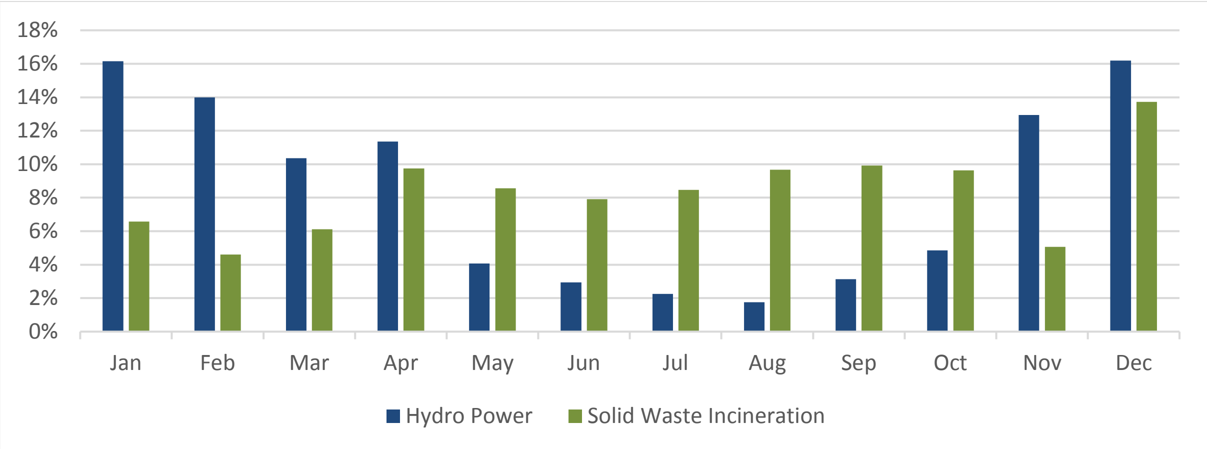

Figure 27: Monthly distribution of energy production from hydro and waste for 2014 on Madeira [28]

3.3.3 Demand

The final part of the energy system in Madeira is the demand side. Table 11: Energy demands on Madeira presents the total sectors' demands, showing the main demand in the electricity sector, of which some might add up to be used in the heating and cooling sector. The listed heating demand in Table 11: Energy demands on Madeira results from the various fuels and the solar radiation, which is clearly used for the generation of heat, as presented before. The transport sector includes all aviation, marine and road transport after general efficiency losses, of which 81% is used in vehicles and only 1.4% in marine transport, which might needs to be seen critical due to the island status of Madeira.

However, ships are limited to a ferry connection to the near-lying island of Porto Santo and a low number of private vessels.

Table 11: Energy demands on Madeira

	Demand		Notes
	Electricity demand	838.8 GWh	*Net production and internal consumption* [29], *Incl. heating (domestic, commercial) and cooling*
	Heat demand	183.9 GWh	*Modelled, Excl. industrial heat* [32]
	Cooling demand	?	*Currently part of electricity demand*
	Industry	285.2 GWh	*Incl. industrial heat* [32]
	Transportation	453.5 GWh	*All types and fuels* [32]

Due to insufficient details on the heating and cooling devices using electricity, a share from the electricity demand should be deducted and allocated for other final demands. This also entails that the total heat demand ends up being more than the presented 183.9 GWh. These possible interrelations between the sectors can be of importance in future energy simulations and in a smart energy system but mainly when considering modal shifts.

The electricity demand is further presented through Figure 28 and Figure 29. Based on the energy balances for 2014, the main demand is found in the service sector, presumably including a large share of hotels and touristic establishments, followed by the household sector for various electrical appliances. Various industrial electricity demands can be distinguished with the energy balance of Madeira, namely Constructions, Agriculture, Mining and the like. The final and lowest demand in the electricity sector is currently presented by EVs with 0.000008%, which is expected to increase drastically with the approaches suggested within the SMILE project. The total demands are depicted by the hour in Figure 29, displaying a rather stable demand throughout the year with demands between 60 and 140 MW per hour. If the share of electricity used for heating were known, its distribution would follow the distribution of heat demand, presented in Figure 30.

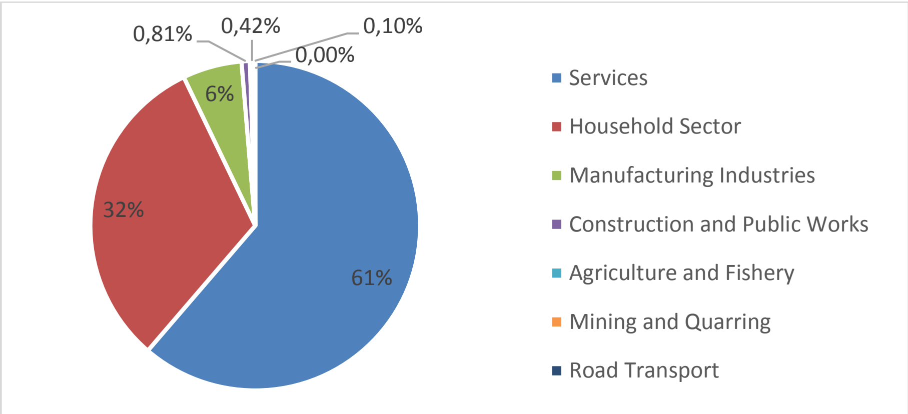

Figure 28: Electricity demand on Madeira by sectors [32]

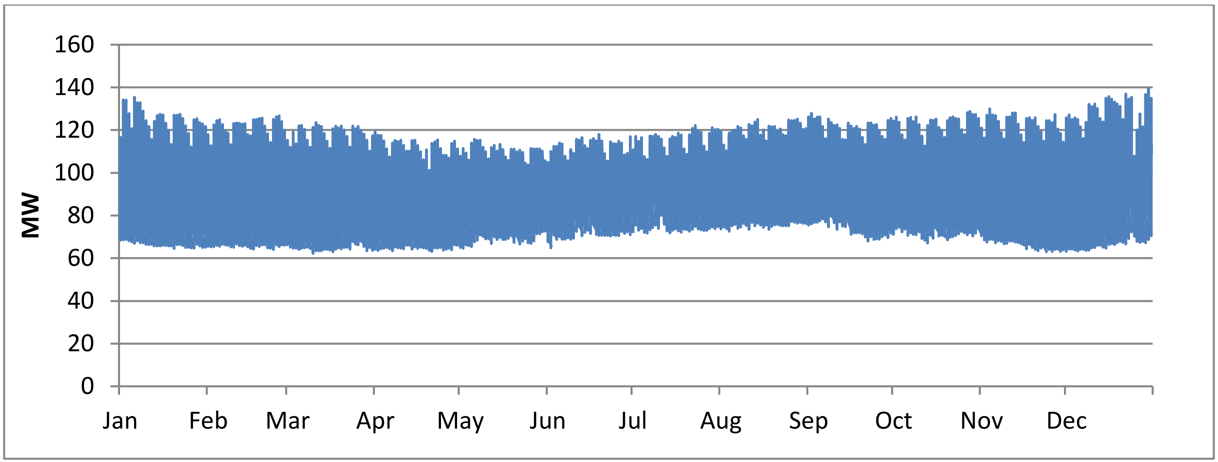

Figure 29: Electricity demand for 2014 on Madeira, based on total productions [28]

The heating and cooling demands are of further interest for modelling. While the share of cooling and electric heating is not known, the distribution of heat can generally be simulated. This is chosen to be done, on the one hand, with degree days and temperatures below 17°C, which occurs mostly between December and April and, on the other hand, with typical daily profiles of hot water usage. On top of that are the numbers of visitors per month taken into account, which results in slight variations as can be seen in the summer months in Figure 30, when no space heat is simulated since the temperatures are above 17°C. This demand profile is applied in EnergyPLAN to distribute fuel demands for heating. In comparison to Samsø and Orkney with its respective sizes, the heat demand on Madeira is very low, as to be expected from a southern island.

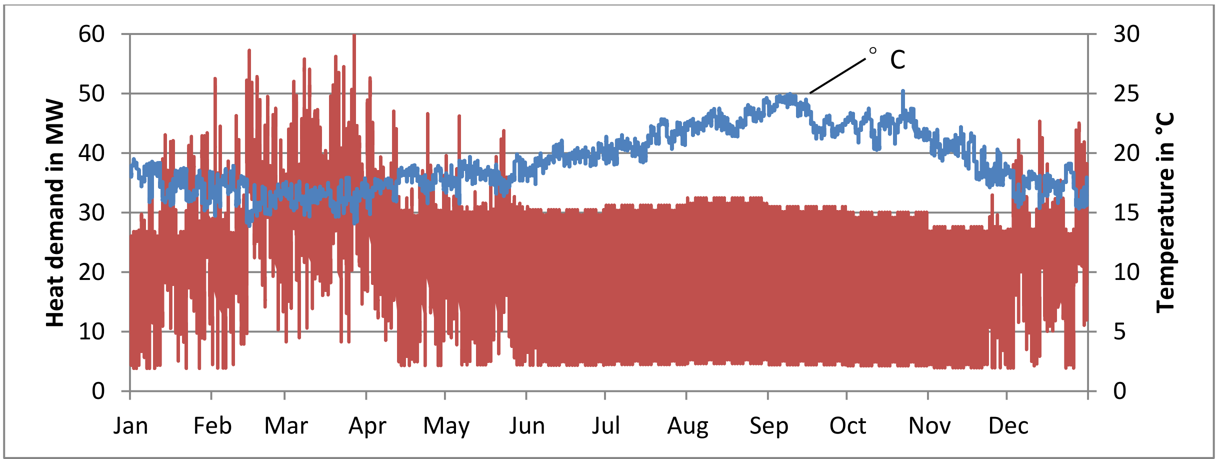

Figure 30: Temperature and resulting heat demand simulation for 2014 on Madeira

The heat demand distribution is only considered for the biomass, oil and gas heaters. If the number or capacities of existing electric heating devices were known, the electricity production could be simulated better. The same applies to cooling demand, where known details could lead to better energy management, for which s similar degree-day approach, but with temperatures above 24°C, could be applied.

The transportation fuels are also modelled as needed, so no distribution profiles are applied. The only exception are EVs for which the charging profile could be interesting to include in the model. With a currently small number of EVs in the model and little knowledge about charging cycles, the charging is assumed to be constant from 20:00 to 7:59 for this reference model of 2014 of Madeira.

3.3.4 Results

Besides some already presented values above, Table 12 sums up the resulting values for the reference model for Madeira as modelled with EnergyPLAN. In the Appendix, the EnergyPLAN printouts are attached, including monthly production and consumption data, as well as annual costs. The details of energy supply, conversion and demand are further presented in the form of a Sankey diagram in Figure 31.

Table 12: Overview of EnergyPLAN results for Madeira

	Madeira reference model
RES share of PES	11%
RES electricity production	239.1 GWh
Imported electricity	-
Exported electricity	-
Oil consumption per year	2910.3 GWh
Gas consumption per year	503.3 GWh
Biomass consumption per year	32.4 GWh
Waste used per year	140.6 GWh
CO_2 emissions per year	894.5 kt

Finally, Figure 31 presents the details of the reference energy system model of Madeira. Due to the inability to import electricity, a large share is produced by a local power plant, which – including the losses – make up the biggest difference to the other pilot islands. In connection to this, the amount of imported fossil fuels is also very large, with the biggest share in fuel oil. In contrast to the values listed in Table 11, the Sankey diagram shows the industrial heat demand of app. 10 GWh in the Heat Demand node and not in the Industrial Demand one, as it can be argued to which category it should belong.

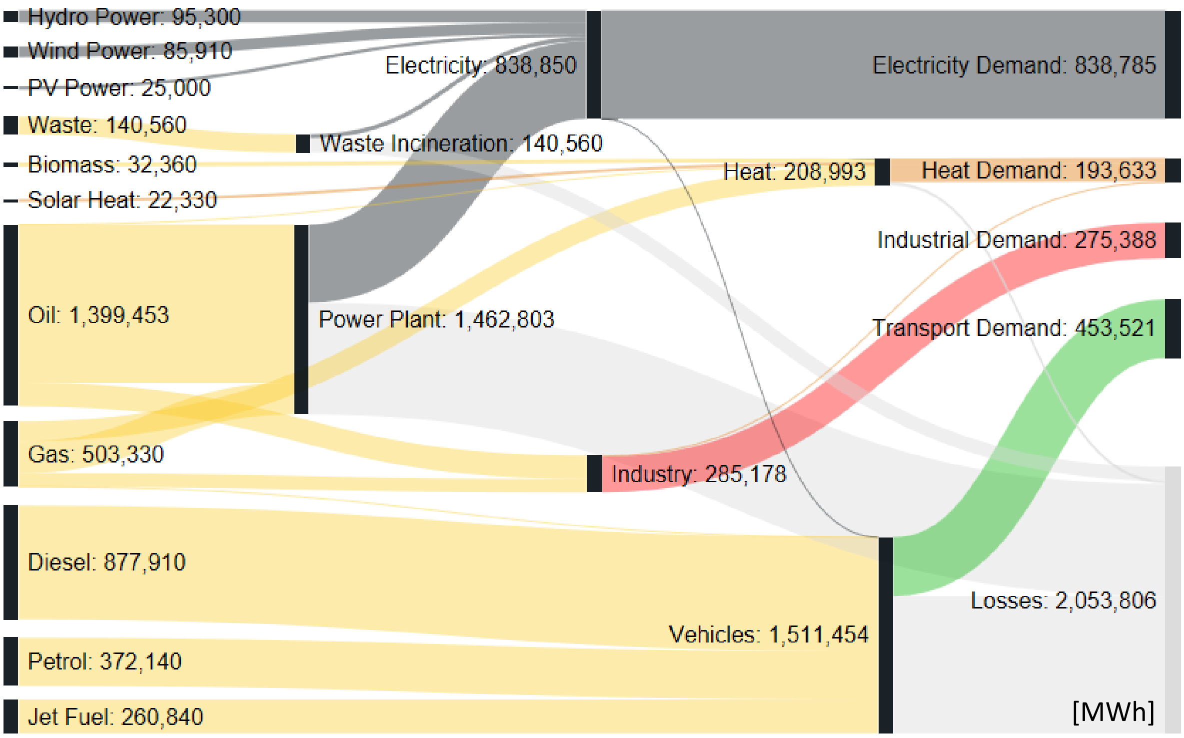

Figure 31: Sankey Diagram of Madeira's reference model of the energy system for 2014

The current energy system of Madeira suffers from an increasing number of electricity demands, e.g. plans for more EVs, while on the other side it also has difficulties to integrate a higher share of fluctuating electricity sources, such as wind turbines and PV. The solutions, which are investigated within the SMILE project, therefore, reach from smart metering and control to battery utilization and improved EV and PV integration. These solutions will be part of Task and Deliverable 8.2, which will build upon this reference system.

4 Demonstrator Comparison

In the following, some of the cornerstones of the reference models are presented in a comparable way in various tables. This enables the direct evaluation of the pilot islands' energy systems, e.g. by comparing the demands in relation to the islands' characteristics, such as number of inhabitants. The comparable tables follow the overall topics of demands with Table 13, electricity production in Table 14, heat production in Next to the electricity production is the heat production a main energy system focus. Table 15 presents the production of heat from oil, biomass, gas, electricity, coal and solar, showing where each islands' priorities lie. 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. Another aspect is the small amount of heat listed for Madeira, either because there is more unknown heat coming from electric heating devices, but also due to its warm climate resulting in a lower demand. Table 15 and fuel consumption in Table 16. Additionally, the tables can be used for easier and faster comparison once the future RE scenarios are done as part of Task 8.2.

With Table 13, the demands of Madeira can be evaluated as rather small for the population and number of tourists. Another interesting aspect is the utilisation of marine vehicles for transportation, which is the biggest in Orkney, presumably due to the large number of small islands that need to be connected.

The included ratios and values per capita can help understand when the islands align despite their different sizes, but also point out the more often occurring differences. The ratio of the population is clearly not represented in the energy related topics' ratios. However, Figure 32 at the end of this Chapter presents the final demands of the islands, including the population ratio in the choice of the verticle-axis.

Table 13: Comparison of energy demands in the reference models of Samsø, Orkney and Madeira

Annual reference data	**Samsø**	**Orkney**	**Madeira**
Inhabitants (ca.)	3,700	22,000	250,000
Ratio of inhabitants	*1*	*5.9*	*67.6*
Electricity Demand (GWh) (incl. electric heat)	25.5	154.7	838.8
Electricity demand per capita (MWh)	*6.9*	*7.0*	*3.4*
Heat Demand (GWh) +Electric (incl. in electricity demand)	46.0 +5.9	69.4 +54.1	193.6 +?
Heat demand per capita (MWh)	*14.0*	*5.6*	*0.8*
Cooling Demand	-	-	?
Transportation Fuel Demand (+Ferries) (GWh) Resulting Demand	99.5 (52.4) 30.0	346.1 (228) 103.9	1511.4 (21.5) 453.5
Transport demand per capita (MWh)	8.1	4.7	1.8
Industry Demand (GWh)	0.4	189.4	275.4

Table 14 points out the capacities and productions from the various RES, where the wind power production is somewhat similar for all islands, while PV the production per capacity is surprisingly best for Samsø and worst for Madeira. Otherwise, Samsø has a rather simply supply system, utilizing only wind and PV systems, while Madeira produces its electricity in the most complex way with five different energy sources. The differences might be the result from the various types of data acquisition, as statistical data can differ from reality as self-consumption might not be considered, while the PV production fed to the grid is definitely after the owner's self-consumption.

Table 14: Comparison of electricity production in the reference models of Samsø, Orkney and Madeira

Annual reference data	Samsø	Orkney	Madeira
Electricity supply (Power Plant, MW)	-	10.5 (+15 back-up)	203.0
PP power supply	-	41.9	599.7
Wind power capacity (MW)	34.4	48.3	45.1
Wind power supply (GWh)	108.4	149.7	85.9
Wind turbines avg. capacity factor	0.37	0.35	0.22
PV capacity (MW)	1.3	1.2	19.1
PV power supply (GWh)	3.1	1.2	25.0
PV panels avg. capacity factor	0.27	0.13	0.15
Hydro power capacity (MW)	-	-	50.7
Hydro power supply (GWh)	-	-	95.3
Hydro plants avg. capacity factor	-	-	0.28
Waste incineration (GWh)	-	-	32.9
Transmission capacity (MW)	40	40	-

Next to the electricity production is the heat production a main energy system focus. Table 15 presents the production of heat from oil, biomass, gas, electricity, coal and solar, showing where each islands' priorities lie. 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. Another aspect is the small amount of heat listed for Madeira, either because there is more unknown heat coming from electric heating devices, but also due to its warm climate resulting in a lower demand.

Table 15: Comparison of heat production in the reference models of Samsø, Orkney and Madeira

Annual reference data	Samsø	Orkney	Madeira
Heat production, district (GWh)	17.0 (biomass)	-	9.8 (industrial)
Heat from oil (GWh)	10.0	60.8	0.1
Heat from biomass (GWh)	17.7	1.4	22.7
Heat from gas (GWh)	-	1.2	138.9
Heat from electricity (GWh)	5.9	54.1	?
Heat from coal (GWh)	-	6.0	-
Heat from solar (GWh)	1.4	0.1	22.3
Total heat production (GWh)	51.9	123.5	193.6

A final comparison is presented in Table 16, listing the various fuels consumed on each island. While the Sankey diagrams of Figure 10, Figure 19 and Figure 31 are not directly comparable, since they show rather the shares than the absolute numbers, Table 16 enables the comparison of the total amounts, showing the large consumptions on Madeira. Nonetheless, the fuel consumption on Madeira does not align with the number of inhabitants, when compared to one of the smaller islands. This could partly be due to the reduced heating demand.

Table 16: Comparison of fuel consumption in the reference models of Samsø, Orkney and Madeira

Annual reference data	Samsø	Orkney	Madeira
Oil consumption (GWh)	89.0	598.8	2910.3

Biomass consumption (GWh)	52.2	2.0	172.9[4]
Gas consumption (GWh)	23.4	94.5	503.3
Coal consumption (GWh)	-	21.1	-
Total consumption (GWh)	164.6	716.4	3586.6
Total consumption per capita (MWh)	*44.5*	*32.6*	*14.3*

The last table includes the data used in the reference models for the creation and application of respective distribution files. Some data is extracted from the same sources, so they can be assumed comparable on a certain level, while differences, such as in electricity profiles can point to areas of less compatibility.

Table 17: Overview of distribution profiles used in the reference models of Samsø, Orkney and Madeira

	Samsø	Orkney	Madeira
Type	Source/Simulation		
Temperature, solar radiation, wind, rain	CFSR	CFSR	CFSR
Solar PV	MERRA simulation	MERRA simulation	Production data
Wind power	MERRA simulation	MERRA simulation	Production data
Solar thermal	CFSR, energyPRO (simulation)	CFSR, energyPRO (simulation)	CFSR, energyPRO (simulation)
Hydro power	-	-	Production data
Waste power	-	-	Production data
Electricity demand	Danish study "energy account" (simulation)	Entso-e power statistics for GB (simulation)	Total production data "energy balance"
Heat demand	Temperature based, incl. tourism for indv. and losses for DH buildings (simulation)	Temperature based (simulation)	Temperature based, incl. tourism (simulation)
Transportation demand/charging for EVs	Dump charge 20:00-7:59 (simulation)	Dump charge 20:00-7:59 (simulation)	Dump charge 20:00-7:59 (simulation)

Similar to the Result Sections 3.1.4, 3.2.4 and 3.3.4, where the Sankey diagrams give the final overview of the energy systems, the demands are presented for all pilot islands in Figure 32. This comparison is done with the vertical-axis in the ratio of 1:6:60, similar to the population ratio of the Samsø, Orkney and Madeira. This points out the general alignment of Samsø's and Orkney's total demand, even though the industrial demand is much greater on Orkney. Furthermore, the lower total heat demands on Orkney could lead to the assumption that the demands are really lower, either due to slightly lower number of degree days or due to high heating prices, but it could also point to data gaps.

However, when comparing to Madeira, the energy systems can simply be deviating due to different cultures and habits. Obviously, the heat demand can be expected to be much lesser than on the other islands, but also the electricity demand is lower per capita. Furthermore, Figure 32 shows that the total losses are the lowest per capita on Madeira, even though the oil consumption in the power plant and

[4] Incl. Waste of 140.6 GWh

its losses are very high.

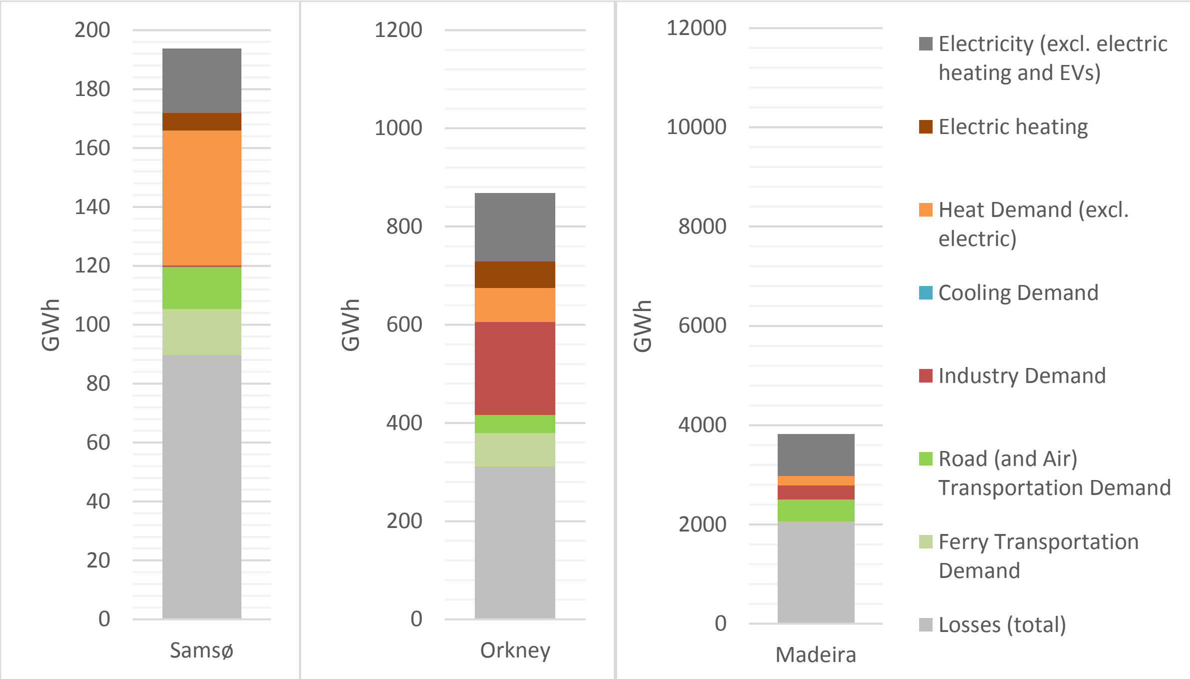

Figure 32: Comparison of final demands in the reference models of Samsø, Orkney and Madeira

5 Conclusions

The reference models of Samsø, Orkney and Madeira are made with a thorough study and in cooperation with the project partners of each respective island. By this, errors and deviations from the real energy system are kept to a minimum, but also awareness is raised of what the islands' energy system consist of and what are major demands, fuels, etc.

On Samsø, the main demands are electricity and heating with 25.5 GWh and 51.9 GWh respectively. Another sector is transportation with 30.1 GWh. With a high number of wind turbines and solar collectors, the PES is supplied by 60% with RES, and a large extent of the produced electricity (78%) is currently exported via the transmission line to the mainland. The reference model also presents a currently high amount of fuels used for combustion processes: 89.0 GWh oil, 23.4 GWh gas and 52.2 GWh biomass, resulting in annual CO_2 emissions of 28.5 kt.

The Orkney Islands are presented with 154.7 GWh electricity and 123.5 GWh heating demand, but also high demands for industrial purposes (189.8 GWh) and transportation (103.9 GWh). Even though Orkney has a large amount of turbines for British standards, the RES covers barely the electricity demand and only 17% of the PES of the whole energy system. The reference model includes electricity production from the local oil terminal, using process gas for local production of electricity and heat; as well as import and export through the mainland cable connection. The total amount of fuels required for this energy system includes 598.8 GWh oil, 21.1 GWh coal, 94.5 GWh gas and 2.0 GWh biomass with a total CO_2 production of 186.2 kt annually.

Finally, Madeira presents the biggest SMILE Island with 838.8 GWh electricity demand, 183.9 GWh for heating, 285.2 GWh industrial and 453.5 GWh transportation demand. Since the detailed use of electricity is not possible to divide into demands for heating, cooling and others, the final demands for these two sectors are presented incomplete. In contrast to Samsø and Orkney, Madeira has not only wind turbines and solar collectors, but also hydro power plants and local waste incineration, resulting in 11% of PES supplied by RES. With no connection to the mainland and no option for export and import of electricity, Madeira's energy system presents itself with a strain on its local grid. Oil, gas, biomass and waste are used to a large extend with 2910.3 GWh, 503.3 GWh, 32.4 GWh and 140.6 GWh, however, not as large as to be expected from such a large island. The total production of CO_2 locally amounts to 894.5 kt per year.

A consistency of data sources was a major issue hard to achieve, while another one was the definition of what belongs to the respective islands. For example, are transportation fuels to and from the islands part of the local energy system, even though they might be bought on the mainland or serving customers, who do not live on the islands themselves. Another concrete example is the Flotta oil terminal on one of the Orkney Isles, but it does not serve the inhabitants strictly as its purpose is to transport oils off the Isles. Finally, weather data and other distribution profiles, which have a high impact on the outcome of the model, need to be seen critical and considered as such.

In the following, the reference models are used to establish and simulate short to medium term high RE scenarios for the pilot islands. This is part of Task and Deliverable 8.2 - Medium term scenarios for the three pilot islands, as presented in Section 2.1.3. For this, the critical areas of the reference models will be considered and solutions implemented as suitable. Additionally, the SMILE context will be elaborated more as new technologies and the implementation of the WP2-4 are furthermore considered. This deliverable follows in December 2018.

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7 Appendix

Input — Samsø Reference 2015.txt — The EnergyPLAN model 12.4

Electricity demand (GWh/year): Flexible demand 0,00
Fixed demand 25,51 Fixed imp/exp. 0,00
Electric heating + HP 0,00 Transportation 0,17
Electric cooling 0,00 Total 25,68

District heating (GWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0,00	25,46	0,00	25,46
Solar Thermal	0,00	1,00	0,00	1,00
Industrial CHP (CSHP)	0,00	0,00	0,00	0,00
Demand after solar and CSHP	0,00	24,46	0,00	24,46

Wind	11359 kW	27,50 GWh/year	0,00	Grid
Offshore Wind	23000 kW	80,9 GWh/year	0,00	stabili-
Photo Voltaic	1337 kW	3,14 GWh/year	0,00	sation
River Hydro	0 kW	0 GWh/year	0,00	share
Hydro Power	0 kW	0 GWh/year		
Geothermal/Nuclear	0 kW	0 GWh/year		

	Capacities kW-e	Capacities kJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0,39	0,46	
Heat Pump	0	0			3,00
Boiler		7000		0,93	
Group 3:					
CHP	0	0	0,40	0,50	
Heat Pump	0	0			3,00
Boiler		0		0,90	
Condensing	0		0,45		

Heatstorage: gr.2: 0 MWh gr.3: 0 MWh
Fixed Boiler: gr.2: 1,0 Per cent gr.3: 0,0 Per cent

Electricity prod. from	CSHP	Waste (GWh/year)
Gr.1:	0,00	0,00
Gr.2:	0,00	0,00
Gr.3:	0,00	0,00

Regulation Strategy: Technical regulation no. 2
CEEP regulation 200000000
Minimum Stabilisation share 0,00
Stabilisation share of CHP 0,00
Minimum CHP gr 3 load 0 kW
Minimum PP 0 kW
Heat Pump maximum share 1,00
Maximum import/export 40000 kW
20141203-distr-elpris-EUR-dkvest-v1.txt
Addition factor 0,00 EUR/MWh
Multiplication factor 1,00
Dependency factor 0,00 EUR/MWh pr. MW
Average Market Price 39 EUR/MWh
Gas Storage 0 MWh
Syngas capacity 0 kW
Biogas max to grid 0 kW

Fuel Price level: Basic

	Capacities kW-e	Storage MWh	Efficiencies elec.	Ther.
Hydro Pump:	0	0	0,80	
Hydro Turbine:	0		0,90	
Electrol. Gr.2:	0	0	0,80	0,10
Electrol. Gr.3:	0	0	0,80	0,10
Electrol. trans.:	0	0	0,80	
Ely. MicroCHP:	0	0	0,80	
CAES fuel ratio:	0,000			

(GWh/year)	Coal	Oil	Ngas	Biomass
Transport	0,00	76,49	22,98	0,00
Household	0,00	12,82	0,00	25,98
Industry	0,00	0,00	0,00	0,00
Various	0,00	0,00	0,42	0,00

Output

	District Heating Demand: Distr. heating kW	Production: Solar kW	Waste CSHP kW	DHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Balance kW	Electricity Consumption: Elec. demand kW	Flex.& Transp kW	HP kW	Elec-trolyser kW	EH kW	Hydro Pump kW	Production: Tur-bine kW	RES kW	Hy-dro kW	Geo-thermal kW	Waste CSHP kW	CHP kW	PP kW	Balance: Stab-Load %	Imp kW	Exp kW	CEEP kW	EEP kW	Exchange Payment Imp 1000 EUR	Exp 1000 EUR
January	4173	12	0	0	0	0	0	4161	0	0	3328	19	0	0	0	0	0	16054	0	0	0	0	0	100	329	13036	0	13036	10	391
February	4542	31	0	0	0	0	0	4512	0	0	3515	19	0	0	0	0	0	13783	0	0	0	0	0	100	117	10365	0	10365	3	282
March	4062	97	0	0	0	0	0	3964	0	0	3168	19	0	0	0	0	0	12254	0	0	0	0	0	100	219	9285	0	9285	7	269
April	3463	193	0	0	0	0	0	3270	0	0	2944	19	0	0	0	0	0	10185	0	0	0	0	0	100	190	7412	0	7412	6	235
May	2759	181	0	0	0	0	0	2578	0	0	2700	19	0	0	0	0	0	12970	0	0	0	0	0	100	66	10317	0	10317	2	281
June	2084	169	0	0	0	0	0	1915	0	0	2448	19	0	0	0	0	0	9720	0	0	0	0	0	100	204	7455	0	7455	5	375
July	1552	196	0	0	0	0	0	1356	0	0	2414	19	0	0	0	0	0	11517	0	0	0	0	0	100	130	9214	0	9214	4	245
August	1278	214	0	0	0	0	0	1064	0	0	2510	19	0	0	0	0	0	9450	0	0	0	0	0	100	172	7093	0	7093	5	207
September	1780	185	0	0	0	0	0	1595	0	0	2598	19	0	0	0	0	0	11615	0	0	0	0	0	100	123	9121	0	9121	3	287
October	2595	57	0	0	0	0	0	2537	0	0	2932	19	0	0	0	0	0	10705	0	0	0	0	0	100	270	8023	0	8023	6	224
November	3119	24	0	0	0	0	0	3095	0	0	3057	19	0	0	0	0	0	15725	0	0	0	0	0	100	167	12815	0	12815	4	323
December	3442	4	0	0	0	0	0	3438	0	0	3249	19	0	0	0	0	0	18360	0	0	0	0	0	100	68	15159	0	15159	2	317
Average	2898	114	0	0	0	0	0	2785	0	0	2904	19	0	0	0	0	0	12699	0	0	0	0	0	100	172	9947	0	9947	Average price	
Maximum	5511	1282	0	0	0	0	0	5511	0	0	4580	39	0	0	0	0	0	33651	0	0	0	0	0	100	3714	30925	0	30925	(EUR/MWh)	
Minimum	947	0	0	0	0	0	0	29	0	0	1647	0	0	0	0	0	0	67	0	0	0	0	0	100	0	0	0	0	38	39
GWh/year	25,46	1,00	0,00	0,00	0,00	0,00	0,00	24,46	0,00	0,00	25,51	0,17	0,00	0,00	0,00	0,00	0,00	111,55	0,00	0,00	0,00	0,00	0,00		1,51	87,38	0,00	87,38	5800 E3436	

FUEL BALANCE (GWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	Offsh.	PV	Hydro	Solar.Th.	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (kt): Total	Net
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	76,49	12,50	-	88,99	0,00	88,99	23,71	23,71
N.Gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22,98	-	0,42	23,40	0,00	23,40	4,78	4,78
Biomass	-	-	-	26,39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25,83	-	52,22	0,00	52,22	0,00	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	27,50	80,90	3,14	-	1,36	-	-	-	112,90	0,00	112,90	0,00	0,00
H2 etc.	-	-	-	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	-	-	-	26,39	-	-	-	-	-	-	-	-	27,50	80,90	3,14	-	1,36	99,47	38,33	0,42	277,51	-190,82	86,69	28,48	28,48

Output specifications — Samsø Reference 2015.txt — The EnergyPLAN model 12.4

District Heating Production

	Gr.1 District heating kW	Gr.1 Solar kW	Gr.1 CSHP kW	Gr.1 DHP kW	Gr.2 District heating kW	Gr.2 Solar kW	Gr.2 CSHP kW	Gr.2 CHP kW	Gr.2 HP kW	Gr.2 ELT kW	Gr.2 Boiler kW	Gr.2 EH kW	Gr.2 Stor-age kW	Gr.2 Ba-lance kW	Gr.3 District heating kW	Gr.3 Solar kW	Gr.3 CSHP kW	Gr.3 CHP kW	Gr.3 HP kW	Gr.3 ELT kW	Gr.3 Boiler kW	Gr.3 EH kW	Gr.3 Stor-age kW	Gr.3 Ba-lance kW	RES specification: RES1 Wind kW	RES2 Offshc kW	RES3 Photo kW	RES 4-7 kW	Total ak kW
January	0	0	0	0	4173	12	0	0	0	0	4161	0	0	0	0	0	0	0	0	0	0	0	0	0	4371	11577	106	0	16054
February	0	0	0	0	4542	31	0	0	0	0	4512	0	0	0	0	0	0	0	0	0	0	0	0	0	3436	10147	201	0	13783
March	0	0	0	0	4062	97	0	0	0	0	3964	0	0	0	0	0	0	0	0	0	0	0	0	0	2935	8975	344	0	12254
April	0	0	0	0	3463	193	0	0	0	0	3270	0	0	0	0	0	0	0	0	0	0	0	0	0	2323	7377	486	0	10185
May	0	0	0	0	2759	181	0	0	0	0	2578	0	0	0	0	0	0	0	0	0	0	0	0	0	3043	9394	534	0	12970
June	0	0	0	0	2084	169	0	0	0	0	1915	0	0	0	0	0	0	0	0	0	0	0	0	0	2204	6950	566	0	9720
July	0	0	0	0	1552	196	0	0	0	0	1356	0	0	0	0	0	0	0	0	0	0	0	0	0	2738	8223	556	0	11517
August	0	0	0	0	1278	214	0	0	0	0	1064	0	0	0	0	0	0	0	0	0	0	0	0	0	2109	6840	502	0	9450
September	0	0	0	0	1780	185	0	0	0	0	1595	0	0	0	0	0	0	0	0	0	0	0	0	0	2728	8451	437	0	11615
October	0	0	0	0	2595	57	0	0	0	0	2537	0	0	0	0	0	0	0	0	0	0	0	0	0	2523	7881	301	0	10705
November	0	0	0	0	3119	24	0	0	0	0	3095	0	0	0	0	0	0	0	0	0	0	0	0	0	4178	11383	164	0	15725
December	0	0	0	0	3442	4	0	0	0	0	3438	0	0	0	0	0	0	0	0	0	0	0	0	0	4972	13297	90	0	18360
Average	0	0	0	0	2898	114	0	0	0	0	2785	0	0	0	0	0	0	0	0	0	0	0	0	0	3131	9210	357	0	12699
Maximum	0	0	0	0	5511	1282	0	0	0	0	5511	0	0	0	0	0	0	0	0	0	0	0	0	0	10788	22454	1300	0	33651
Minimum	0	0	0	0	947	0	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	9	40	0	0	67
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	25,46	1,00	0,00	0,00	0,00	0,00	24,46	0,00		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		0,00	27,50	80,90	3,14	0,00	111,55

Own use of heat from Industrial CH 0,00 GWh/year

ANNUAL COSTS (1000 EUR)		
Total Fuel ex Ngas exchange =		7149
Uranium =	0	
Coal =	0	
FuelOil =	0	
Gasoil/Diesel=	4740	
Petrol/JP =	784	
Gas handling =	0	
Biomass =	1625	
Food income =	0	
Waste =	0	
Total Ngas Exchange costs =		767
Marginal operation costs =		4
Total Electricity exchange =		-3378
Import =	58	
Export =	-3436	
Bottleneck =	0	
Fixed imp/ex=	0	
Total CO2 emission costs =		815
Total variable costs =		5355
Fixed operation costs =		8364
Annual Investment costs =		7051
TOTAL ANNUAL COSTS =		20770

NATURAL GAS EXCHANGE

	DHP & Boilers kW	CHP2 CHP3 kW	PP CAES kW	Indi-vidual kW	Trans port kW	Indu. Var. kW	Demand Sum kW	Bio-gas kW	Syn-gas kW	CO2Hy gas kW	SynHy gas kW	SynHy gas kW	Stor-age kW	Sum kW	Im-port kW	Ex-port kW
January	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
February	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
March	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
April	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
May	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
June	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
July	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
August	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
September	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
October	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
November	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
December	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
Average	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
Maximum	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
Minimum	0	0	0	0	2616	48	2664	0	0	0	0	0	0	2664	2664	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	22,98	0,42	23,40	0,00	0,00	0,00	0,00	0,00	0,00	23,40	23,40	0,00

RES Share: 59,5 Percent of Primary Energ434,4 Percent of Electricity 111,5 GWh electricity from RES 17-januar-2018 [10:22]

Input Orkney Reference 2014.txt — The EnergyPLAN model 12.4

Electricity demand (GWh/year): Flexible demand 0,00
Fixed demand 139,39 Fixed imp/exp. 0,00
Electric heating + HP 15,29 Transportation 0,07
Electric cooling 0,00 Total 154,76

District heating (GWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0,00	0,00	0,00	0,00
Solar Thermal	0,00	0,00	0,00	0,00
Industrial CHP (CSHP)	0,00	0,00	0,00	0,00
Demand after solar and CSHP	0,00	0,00	0,00	0,00

Wind	48343 kW	149,68 GWh/year	0,00	Grid
Wind	0 kW	0 GWh/year	0,00	stabili-
Photo Voltaic	1295 kW	1,21 GWh/year	0,00	sation
Wind	0 kW	0 GWh/year	0,00	share
Hydro Power	0 kW	0 GWh/year		
Geothermal/Nuclear	0 kW	0 GWh/year		

	Capacities kW-e	Capacities kJ/s	Efficiencies elec.	Efficiencies Ther	Efficiencies COP
Group 2:					
CHP	0	0	0,40	0,50	
Heat Pump	0	0			3,00
Boiler		0		0,90	
Group 3:					
CHP	0	0	0,40	0,50	
Heat Pump	100	300			3,00
Boiler		0		0,90	
Condensing	10500		0,45		

Heatstorage: gr.2: 0 MWh gr.3: 0 MWh
Fixed Boiler: gr.2: 0,0 Per cent gr.3: 0,0 Per cent

Electricity prod. from	CSHP	Waste (GWh/year)
Gr.1:	0,00	0,00
Gr.2:	0,00	0,00
Gr.3:	0,00	0,00

Regulation Strategy: Technical regulation no. 1
CEEP regulation 100000000
Minimum Stabilisation share 0,00
Stabilisation share of CHP 0,00
Minimum CHP gr 3 load 0 kW
Minimum PP 0 kW
Heat Pump maximum share 0,50
Maximum import/export 40000 kW

Distr. Name : Hour_nordpool.txt
Addition factor 0,00 EUR/MWh
Multiplication factor 2,00
Dependency factor 0,00 EUR/MWh pr. MW
Average Market Price 227 EUR/MWh
Gas Storage 0 MWh
Syngas capacity 0 kW
Biogas max to grid 0 kW

Fuel Price level: Basic

	Capacities kW-e	Storage MWh	Efficiencies elec.	Ther.
Hydro Pump:	0	0	0,80	
Hydro Turbine:	0		0,90	
Electrol. Gr.2:	0	0	0,80	0,10
Electrol. Gr.3:	0	0	0,80	0,10
Electrol. trans.:	0	0	0,80	
Ely. MicroCHP:	0	0	0,80	
CAES fuel ratio:	0,000			

(GWh/year)	Coal	Oil	Ngas	Biomass
Transport	0,00	346,07	0,00	0,00
Household	8,50	76,06	1,37	2,00
Industry	12,60	176,75	0,00	0,00
Various	0,00	0,00	0,00	0,00

Output

District Heating: Demand / Production. Electricity: Consumption / Production / Balance. Exchange: Payment (1000 EUR).

	DH Distr. heating kW	Solar kW	Waste CSHP kW	DHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Ba-lance kW	Elec. demand kW	Flex.& Transp kW	HP kW	Elec-trolyser kW	EH kW	Hydro Pump kW	Tur-bine kW	RES kW	Hy-dro kW	Geo-thermal kW	Waste-CSHP kW	CHP kW	PP kW	Stab-Load %	Imp kW	Exp kW	CEEP kW	EEP kW	Payment Imp	Exp
January	0	0	0	0	0	0	0	0	0	0	17806	9	2499	0	0	0	0	26707	0	0	0	0	2500	100	637	9530	0	9530	103	2237
February	0	0	0	0	0	0	0	0	0	0	17197	9	2665	0	0	0	0	24553	0	0	0	0	3163	100	1034	8881	0	8881	196	1309
March	0	0	0	0	0	0	0	0	0	0	16156	8	2516	0	0	0	0	22723	0	0	0	0	3820	100	1121	8984	0	8984	190	1351
April	0	0	0	0	0	0	0	0	0	0	14772	9	2318	0	0	0	0	15913	0	0	0	0	4567	100	915	4297	0	4297	170	866
May	0	0	0	0	0	0	0	0	0	0	14286	9	1859	0	0	0	0	8761	0	0	0	0	6948	100	1791	1346	0	1346	387	227
June	0	0	0	0	0	0	0	0	0	0	14661	9	1296	0	0	0	0	6841	0	0	0	0	7611	100	1993	480	0	480	315	60
July	0	0	0	0	0	0	0	0	0	0	15201	9	710	0	0	0	0	9124	0	0	0	0	6764	100	1541	1509	0	1509	177	177
August	0	0	0	0	0	0	0	0	0	0	14495	9	842	0	0	0	0	14135	0	0	0	0	4425	100	605	3820	0	3820	103	586
September	0	0	0	0	0	0	0	0	0	0	15712	9	824	0	0	0	0	11042	0	0	0	0	6767	100	1809	3073	0	3073	330	489
October	0	0	0	0	0	0	0	0	0	0	15793	9	1315	0	0	0	0	20663	0	0	0	0	3601	100	1161	8309	0	8309	216	1514
November	0	0	0	0	0	0	0	0	0	0	17452	9	1661	0	0	0	0	18471	0	0	0	0	4677	100	1618	5645	0	5645	276	903
December	0	0	0	0	0	0	0	0	0	0	16958	9	2411	0	0	0	0	27154	0	0	0	0	2455	100	576	10809	0	10809	94	2043
Average	0	0	0	0	0	0	0	0	0	0	15869	9	1740	0	0	0	0	17179	0	0	0	0	4771	100	1231	5563	0	5563	Average price	
Maximum	0	0	0	0	0	0	0	0	0	0	25041	17	3521	0	0	0	0	49082	0	0	0	0	10500	100	14746	37976	0	37976	(EUR/MWh)	
Minimum	0	0	0	0	0	0	0	0	0	0	8505	0	79	0	0	0	0	74	0	0	0	0	0	100	0	0	0	0	236	241
GWh/year	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	139,39	0,08	15,29	0,00	0,00	0,00	0,00	150,90	0,00	0,00	0,00	0,00	41,91		10,81	48,86	0,00	48,86	255600	11762

FUEL BALANCE (GWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	Wind	PV	Wind	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (kt): Total	Net
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8,50	12,60	21,10	0,00	21,10	7,22	7,22
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	346,07	76,00	176,75	598,82	0,00	598,82	159,52	159,52
N.Gas	-	-	-	-	-	93,14	-	-	-	-	-	-	-	-	-	-	-	-	1,37	-	94,51	-84,56	9,95	19,29	2,03
Biomass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,00	-	2,00	0,00	2,00	0,00	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	149,68	-	1,21	-	0,05	-	-	-	150,95	0,00	150,95	0,00	0,00
H2 etc.	-	-	-	-	-	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	-	-	-	-	-	93,14	-	-	-	-	-	-	149,68	-	1,21	-	0,05	346,07	87,87	189,36	867,37	-84,56	782,81	186,03	168,77

Output specifications Orkney Reference 2014.txt — The EnergyPLAN model 12.4

District Heating Production

	Gr.1 District heating kW	Gr.1 Solar kW	Gr.1 CSHP kW	Gr.1 DHP kW	Gr.2 District heating kW	Gr.2 Solar kW	Gr.2 CSHP kW	Gr.2 CHP kW	Gr.2 HP kW	Gr.2 ELT kW	Gr.2 Boiler kW	Gr.2 EH kW	Gr.2 Stor-age kW	Gr.2 Ba-lance kW	Gr.3 District heating kW	Gr.3 Solar kW	Gr.3 CSHP kW	Gr.3 CHP kW	Gr.3 HP kW	Gr.3 ELT kW	Gr.3 Boiler kW	Gr.3 EH kW	Gr.3 Stor-age kW	Gr.3 Ba-lance kW	RES1 Wind kW	RES2 Wind kW	RES3 Photo kW	RES 4-7 kW	Total kW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26690	0	17	0	26707
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24489	0	64	0	24553
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22605	0	118	0	22723
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15712	0	202	0	15913
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8549	0	212	0	8761
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6577	0	265	0	6841
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8871	0	253	0	9124
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13907	0	228	0	14135
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10872	0	170	0	11042
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20582	0	81	0	20663
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18436	0	36	0	18471
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27143	0	12	0	27154
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17040	0	138	0	17179
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48343	0	1031	0	49082
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0	74
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		0,00	149,68	0,00	1,21	0,00	150,90

Own use of heat from industrial CHP 0,00 GWh/year

ANNUAL COSTS (1000 EUR)
Total Fuel ex Ngas exchange = 0
Uranium = 0
Coal = 0
FuelOil = 0
Gasoil/Diesel= 0
Petrol/JP = 0
Gas handling = 0
Biomass = 0
Food income = 0
Waste = 0

Total Ngas Exchange costs = 0

Marginal operation costs = 0

Total Electricity exchange = -9206
Import = 2556
Export = -11762
Bottleneck = 0
Fixed imp/ex= 0

Total CO2 emission costs = 0

Total variable costs = -9206
Fixed operation costs = 0

Annual Investment costs = 0

TOTAL ANNUAL COSTS = -9206

NATURAL GAS EXCHANGE

	DHP & Boilers kW	CHP2 CHP3 kW	PP CAES kW	Indi-vidual kW	Trans port kW	Indu. Var. kW	Demand Sum kW	Bio-gas kW	Syn-gas kW	CO2Hy gas kW	SynHy gas kW	SynHy gas kW	Stor-age kW	Sum kW	Im-port kW	Ex-port kW
January	0	0	5556	224	0	0	5780	0	0	0	0	0	0	5780	5780	0
February	0	0	7029	239	0	0	7268	0	0	0	0	0	0	7268	7268	0
March	0	0	8489	225	0	0	8715	0	0	0	0	0	0	8715	8715	0
April	0	0	10149	208	0	0	10357	0	0	0	0	0	0	10357	10357	0
May	0	0	15440	167	0	0	15606	0	0	0	0	0	0	15606	15606	0
June	0	0	16914	116	0	0	17030	0	0	0	0	0	0	17030	17030	0
July	0	0	15030	64	0	0	15094	0	0	0	0	0	0	15094	15094	0
August	0	0	9833	75	0	0	9909	0	0	0	0	0	0	9909	9909	0
September	0	0	15039	74	0	0	15112	0	0	0	0	0	0	15112	15112	0
October	0	0	8003	118	0	0	8121	0	0	0	0	0	0	8121	8121	0
November	0	0	10392	149	0	0	10541	0	0	0	0	0	0	10541	10541	0
December	0	0	5456	216	0	0	5672	0	0	0	0	0	0	5672	5672	0
Average	0	0	10603	156	0	0	10759	0	0	0	0	0	0	10759	10759	0
Maximum	0	0	23333	316	0	0	23634	0	0	0	0	0	0	23634	23634	0
Minimum	0	0	0	7	0	0	7	0	0	0	0	0	0	7	7	0
Total for the whole year GWh/year	0,00	0,00	93,14	1,37	0,00	0,00	94,51	0,00	0,00	0,00	0,00	0,00	0,00	94,51	94,51	0,00

RES Share: 17,6 Percent of Primary Energy 108,2 Percent of Electricity 150,9 GWh electricity from RES — 17-januar-2018 [10:45]

Input Madeira Reference 2014.txt The EnergyPLAN model 12.4

Electricity demand (GWh/year): Flexible demand 0,00
Fixed demand 838,78 Fixed imp/exp. 0,00
Electric heating + HP 0,00 Transportation 0,06
Electric cooling 0,00 Total 838,84

District heating (GWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0,00	0,00	9,79	9,79
Solar Thermal	0,00	0,00	0,00	0,00
Industrial CHP (CSHP)	0,00	0,00	9,79	9,79
Demand after solar and CSHP	0,00	0,00	0,00	0,00

Wind	45110 kW	85,91 GWh/year	0,00	Grid
Photo Voltaic	19080 kW	25 GWh/year	0,00	stabili-
River Hydro	26690 kW	64,5 GWh/year	0,00	sation
River Hydro	0 kW	0 GWh/year	0,00	share
Hydro Power	24000 kW	30,8 GWh/year		
Geothermal/Nuclear	0 kW	0 GWh/year		

	Capacities kW-e	kJ/s	Efficiencies elec.	Ther	COP
Group 2:					
CHP	0	0	0,40	0,50	
Heat Pump	0	0			3,00
Boiler		0		0,90	
Group 3:					
CHP	0	0	0,40	0,10	
Heat Pump	0	0			3,00
Boiler		0		0,90	
Condensing	203040		0,41		

Heatstorage: gr.2: 0 MWh gr.3: 0 MWh
Fixed Boiler: gr.2: 0,0 Per cent gr.3: 0,0 Per cent

Electricity prod. from	CSHP	Waste (GWh/year)
Gr.1:	0,00	32,89
Gr.2:	0,00	0,00
Gr.3:	0,00	0,00

Regulation Strategy: Technical regulation no. 1
CEEP regulation 000000000
Minimum Stabilisation share 0,30
Stabilisation share of CHP 0,00
Minimum CHP gr 3 load 0 kW
Minimum PP 0 kW
Heat Pump maximum share 0,50
Maximum import/export 0 kW

Distr. Name : Hour_nordpool.txt
Addition factor 0,00 EUR/MWh
Multiplication factor 2,00
Dependency factor 0,00 EUR/MWh pr. MW
Average Market Price 227 EUR/MWh
Gas Storage 0 MWh
Syngas capacity 0 kW
Biogas max to grid 0 kW

Fuel Price level: Basic

	Capacities kW-e	Storage MWh	Efficiencies elec.	Ther.
Hydro Pump:	0	0	0,80	
Hydro Turbine:	0		0,90	
Electrol. Gr.2:	0	0	0,80	0,10
Electrol. Gr.3:	0	0	0,80	0,10
Electrol. trans.:	0	0	0,80	
Ely. MicroCHP:	0	0	0,80	

CAES fuel ratio: 0,000

(GWh/year)	Coal	Oil	Ngas	Biomass
Transport	0,0	1510,89	0,00	0,00
Household	0,00	0,01	179,10	32,36
Industry	0,00	164,88	6,09	0,00
Various	0,00	15,56	98,65	0,00

Output

District Heating

	Demand: Distr. heating kW	Production: Solar kW	Waste CSHP kW	DHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Ba-lance kW
January	1139	0	1115	0	0	0	0	0	0	25
February	1492	0	1115	0	0	0	0	0	0	377
March	1716	0	1115	0	0	0	0	0	0	602
April	1194	0	1115	0	0	0	0	0	0	79
May	1055	0	1115	0	0	0	0	0	0	-59
June	929	0	1115	0	0	0	0	0	0	-185
July	951	0	1115	0	0	0	0	0	0	-163
August	985	0	1115	0	0	0	0	0	0	-129
September	942	0	1115	0	0	0	0	0	0	-172
October	911	0	1115	0	0	0	0	0	0	-204
November	856	0	1115	0	0	0	0	0	0	-259
December	1210	0	1115	0	0	0	0	0	0	96
Average	1115	0	1115	0	0	0	0	0	0	0
Maximum	3253	0	1115	0	0	0	0	0	0	2139
Minimum	205	0	1115	0	0	0	0	0	0	-910
GWh/year	9,79	0,00	9,79	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Electricity / Exchange

	Consumption: Elec. demand MW	Flex.& Transp kW	HP kW	Elec-trolyser kW	EH kW	Hydro Pump kW	Production: Tur-bine kW	RES kW	Hy-dro kW	Geo-thermal kW	Waste-CSHP kW	CHP kW	PP MW	Stab-Load %	Balance: Imp kW	Exp kW	CEEP kW	EEP kW	Payment Imp	Exp
January	95	7	0	0	0	0	0	28277	6676	0	2895	0	57	223	0	0	0	0	0	0
February	93	7	0	0	0	0	0	27246	6333	0	2224	0	57	227	0	0	0	0	0	0
March	90	7	0	0	0	0	0	24386	4477	0	2801	0	59	233	0	0	0	0	0	0
April	90	7	0	0	0	0	0	17346	4591	0	4394	0	63	253	0	0	0	0	0	0
May	92	7	0	0	0	0	0	19657	1663	0	3770	0	67	249	0	0	0	0	0	0
June	96	7	0	0	0	0	0	15376	1226	0	3584	0	75	267	0	0	0	0	0	0
July	99	7	0	0	0	0	0	15532	923	0	3755	0	79	269	0	0	0	0	0	0
August	101	7	0	0	0	0	0	15093	720	0	4280	0	81	269	0	0	0	0	0	0
September	101	7	0	0	0	0	0	11433	1338	0	4510	0	83	280	0	0	0	0	0	0
October	99	7	0	0	0	0	0	17096	2195	0	4074	0	75	261	0	0	0	0	0	0
November	94	7	0	0	0	0	0	23858	5602	0	2505	0	62	240	0	0	0	0	0	0
December	96	7	0	0	0	0	0	24416	6471	0	6043	0	59	227	0	0	0	0	0	0
Average	95	7	0	0	0	0	0	19969	3506	0	3744	0	68	250	0	0	0	0	Average price	(EUR/MWh)
Maximum	140	14	0	0	0	0	0	63655	14086	0	6695	0	119	327	0	0	0	0		
Minimum	63	0	0	0	0	0	0	1082	401	0	0	0	27	136	0	0	0	0	233	223
GWh/year	839	0,06	0,00	0,00	0,00	0,00	0,00	175,41	30,80	0,00	32,89	0,00	600		0,00	0,00	0,00	0,00	1000 EUR	0

FUEL BALANCE (GWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV	Hydro	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (kt): Total	Net
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Oil	-	-	-	-	-	1219,00	-	-	-	-	-	-	-	-	-	-	-	1510,89	0,01	180,44	2910,34	0,00	2910,34	775,32	775,32
N.Gas	-	-	-	-	-	243,80	-	-	-	-	-	-	-	-	-	-	-	0,50	154,29	104,74	503,33	0,00	503,33	102,74	102,85
Biomass	-	-	-	-	-	-	-	-	140,56	-	-	-	-	-	-	-	-	-	32,36	-	172,92	0,00	172,92	16,45	16,45
Renewable	-	-	-	-	-	-	-	30,80	-	-	-	-	85,91	25,00	64,50	-	22,33	-	-	-	228,54	0,00	228,54	0,00	0,00
H2 etc.	-	-	-	-	-	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	-	-	-	-	-	1462,80	-	30,80	140,56	-	-	-	85,91	25,00	64,50	-	22,33	1511,39	186,66	285,18	3815,12	0,00	3815,12	894,50	894,61

Output specifications Madeira Reference 2014.txt The EnergyPLAN model 12.4

District Heating Production

	Gr.1 District heating kW	Solar kW	CSHP kW	DHP kW	Gr.2 District heating kW	Solar kW	CSHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Stor-age kW	Ba-lance kW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		0,00

	Gr.3 District heating kW	Solar kW	CSHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Stor-age kW	Ba-lance kW	RES specification: RES1 Wind kW	RES2 Photo kW	RES3 River kW	RES 4-7 kW	Total kW
January	1139	0	1115	0	0	0	0	0	0	25	12819	1845	13612	0	28277
February	1492	0	1115	0	0	0	0	0	0	377	11765	2379	13102	0	27246
March	1716	0	1115	0	0	0	0	0	0	602	11812	3170	9405	0	24386
April	1194	0	1115	0	0	0	0	0	0	79	4651	3090	9605	0	17346
May	1055	0	1115	0	0	0	0	0	0	-59	11800	4165	3692	0	19657
June	929	0	1115	0	0	0	0	0	0	-185	8896	3746	2733	0	15376
July	951	0	1115	0	0	0	0	0	0	-163	9715	3745	2072	0	15532
August	985	0	1115	0	0	0	0	0	0	-129	9223	4246	1624	0	15093
September	942	0	1115	0	0	0	0	0	0	-172	6310	2174	2949	0	11433
October	911	0	1115	0	0	0	0	0	0	-204	10013	2285	4798	0	17096
November	856	0	1115	0	0	0	0	0	0	-259	10620	1762	11476	0	23858
December	1210	0	1115	0	0	0	0	0	0	96	9586	1494	13336	0	24416
Average	1115	0	1115	0	0	0	0	0	0	0	9780	2846	7343	0	19969
Maximum	3253	0	1115	0	0	0	0	0	0	2139	45110	19080	26690	0	63655
Minimum	205	0	1115	0	0	0	0	0	0	-910	21	0	909	0	1082
Total for the whole year GWh/year	9,79	0,00	9,79	0,00	0,00	0,00	0,00	0,00		0,00	85,91	25,00	64,50	0,00	175,41

Own use of heat from industrial CHP 0,00 GWh/year

ANNUAL COSTS (1000 EUR)
Total Fuel ex Ngas exchange = 158979
Uranium = 0
Coal = 0
FuelOil = 62230
Gasoil/Diesel = 54045
Petrol/JP = 39479
Gas handling = 2153
Biomass = 1072
Food income = 0
Waste = 0

Total Ngas Exchange costs = 16473

Marginal operation costs = 1618

Total Electricity exchange = 0
Import = 0
Export = 0
Bottleneck = 0
Fixed imp/ex = 0

Total CO2 emission costs = 25583

Total variable costs = 202652
Fixed operation costs = 34111

Annual Investment costs = 78954

TOTAL ANNUAL COSTS = 315716

NATURAL GAS EXCHANGE

	DHP & Boilers kW	CHP2 CHP3 kW	PP CAES kW	Indi-vidual kW	Trans port kW	Indu. Var. kW	Demand Sum kW	Bio-gas kW	Syn-gas kW	CO2Hy gas kW	SynHy gas kW	SynHy gas kW	Stor-age kW	Sum kW	Im-port kW	Ex-port kW
January	0	0	23095	19645	0	11924	54663	0	0	0	0	0	0	54663	54663	0
February	0	0	23242	25012	0	11924	60177	0	0	0	0	0	0	60177	60177	0
March	0	0	23878	28601	0	11924	64402	0	0	0	0	0	0	64402	64402	0
April	0	0	25807	18391	0	11924	56122	0	0	0	0	0	0	56122	56122	0
May	0	0	27298	16386	0	11924	55608	0	0	0	0	0	0	55608	55608	0
June	0	0	30627	13484	0	11924	56035	0	0	0	0	0	0	56035	56035	0
July	0	0	32153	14586	0	11924	58662	0	0	0	0	0	0	58662	58662	0
August	0	0	32984	14017	0	11924	58924	0	0	0	0	0	0	58924	58924	0
September	0	0	33882	12968	0	11924	58774	0	0	0	0	0	0	58774	58774	0
October	0	0	30600	13148	0	11924	55671	0	0	0	0	0	0	55671	55671	0
November	0	0	25330	14068	0	11924	51321	0	0	0	0	0	0	51321	51321	0
December	0	0	24022	20587	0	11924	56532	0	0	0	0	0	0	56532	56532	0
Average	0	0	27755	17565	0	11924	57243	0	0	0	0	0	0	57243	57243	0
Maximum	0	0	48172	59517	0	11924	99435	0	0	0	0	0	0	99435	99435	0
Minimum	0	0	10823	0	0	11924	27654	0	0	0	0	0	0	27654	27654	0
Total for the whole year GWh/year	0,00	0,00	243,80	154,29	0,00	104,74	502,83	0,00	0,00	0,00	0,00	0,00	0,00	502,83	502,83	0,00

RES Share: 10,5 Percent of Primary Energy 28,5 Percent of Electricity 239,1 GWh electricity from RES 17-januar-2018 [10:44]