ACCELERATING THE DECARBONIZATION OF
ISLANDS' ENERGY SYSTEMS

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FEASIBILITY STUDY FOR ISLANDER ENERGY COMMUNITY

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Change Control

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1 INTRODUCTION

The ISLANDER project aims to support the creation of a renewable energy community (REC) on the project's pilot island Borkum. An energy community on Borkum will have a lot of advantages for Borkum and its citizens. They allow citizens to participate in the energy transition and increase public acceptance of renewable energy projects. By implementing local sustainability projects, energy communities can achieve energy independence, reduce carbon emissions, and fuel poverty, as well as contribute to the local economy. By becoming co-owners of renewable installations, citizens have democratic influence over energy investments and have local influence over profit sharing. Surpluses can be reinvested in further energy projects, generating local jobs, and attracting new investments. For this to be successful it is important to educate and involve the citizens in the process of decarbonization of energy systems. To put this into reality, the ISLANDER project has developed an action plan which is based on the engagement of the main stakeholders on Borkum to facilitate the creation of a renewable energy community. The main instrument is a series of workshops to find citizens willing to take responsibility for the REC on Borkum and push forward the initiative even after the end of the project.

Previously the ISLANDER project generated a public deliverable which acts as an information package on RECs[1]. The deliverable contains a summary of general information on energy communities in Germany and on the energy transition on Borkum. This led to possible concepts and legal forms of the energy community on Borkum. Much potential is seen in concentrating on the development of solar PV systems with battery storage and a local heating network together with the local utility provider and ISLANDER project partner NBG and the city council. These ideas will be elaborated during the engagement processes and especially in discussions with NBG and the municipalities. To communicate this information to possible stakeholders and participants of the energy community on Borkum, communication and information channels, a questionnaire, infographics, and a public letter are provided within the already published deliverable D7.3.

This deliverable builds on the previous work and aims to supply the REC with feasible case studies concerned with projects to successfully push forward the energy transition. The main target was to study different technologies available and test them regarding economic viability and technical feasibility, always taking the viewpoint of the citizens, local businesses and a REC. The deliverable benefits from the large set of different technological solutions being developed and implemented on Borkum within the ISLANDER project itself. The goal is to find economically feasible cases and business models that can serve as initial projects to kick-off the creation of a REC on Borkum.

2 SITUATION ON BORKUM

The situation on Borkum and existing results of an external study were already discussed in detail in the deliverable D7.3 "Infopack for citizen engagement" as mentioned in the introduction, which is publicly available on the ISLANDER webpage. Here only a short overview is given, and specifics related to the individual interventions that might be of interest for renewable energy communities are discussed later in the respective chapters.

Borkum has ca. 5,500 permanent residents and over 25,000 people are on the island during tourist season. It has a yearly energy consumption of ca. 235 GWh. Thereof, 60 % is used for

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[1] D7.3-Infopack-for-citizen-engagement_V4.0.pdf (islander-project.eu)

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heat production via imported natural gas. 20 % of energy is used for maritime and road transport via fossil fuels. And 20 % is made up of electricity, where most of it is imported from the mainland via a sea power cable. Today only ca. 6 % of the overall energy consumption is produced on the island via renewable energy sources, namely photovoltaics and wind energy.

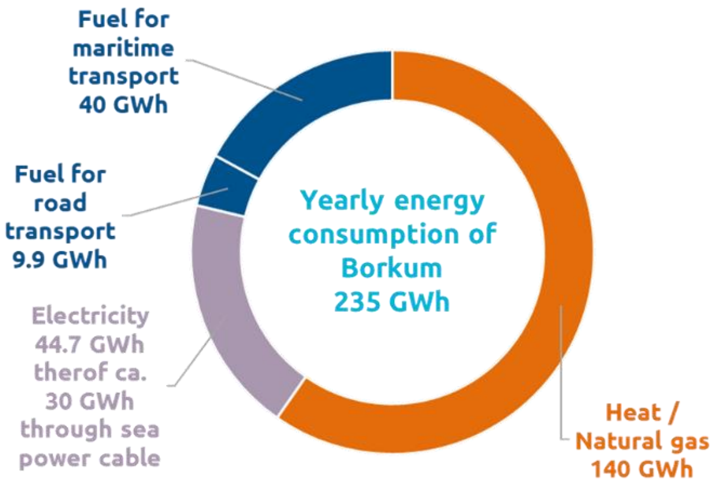

Figure 1: Energy demand of Borkum.

In 2021 an external study was contracted by the utility company of Borkum to assess the possibilities to sustainably serve the heating demand of the island. It was identified that a heating network can be the backbone of the energy transition on Borkum. There are two potential heat sources being discussed now, a seawater heat pump and geothermal energy. A sea water heat pump is an inexhaustible source of heat but requires electricity as an input to operate. Geothermal energy on the other hand has the potential to produce heat and electricity using hot water from several kilometers deep under the island.

In addition to the heat sources, photovoltaics could contribute about 50 % of the current electricity needs if all available roofs and open areas on the island are being utilized. The external study also looked at different possibilities to stabilize the future sustainable energy system of Borkum. This could e.g. be done by storing hydrogen during times of excess electricity and producing heat and electricity with hydrogen powered combined heat and power plants (CHP) during times of peak demand.

In the following figure, a map is shown with some indications for potential locations of renewable energy installations and their potential on the island of Borkum.

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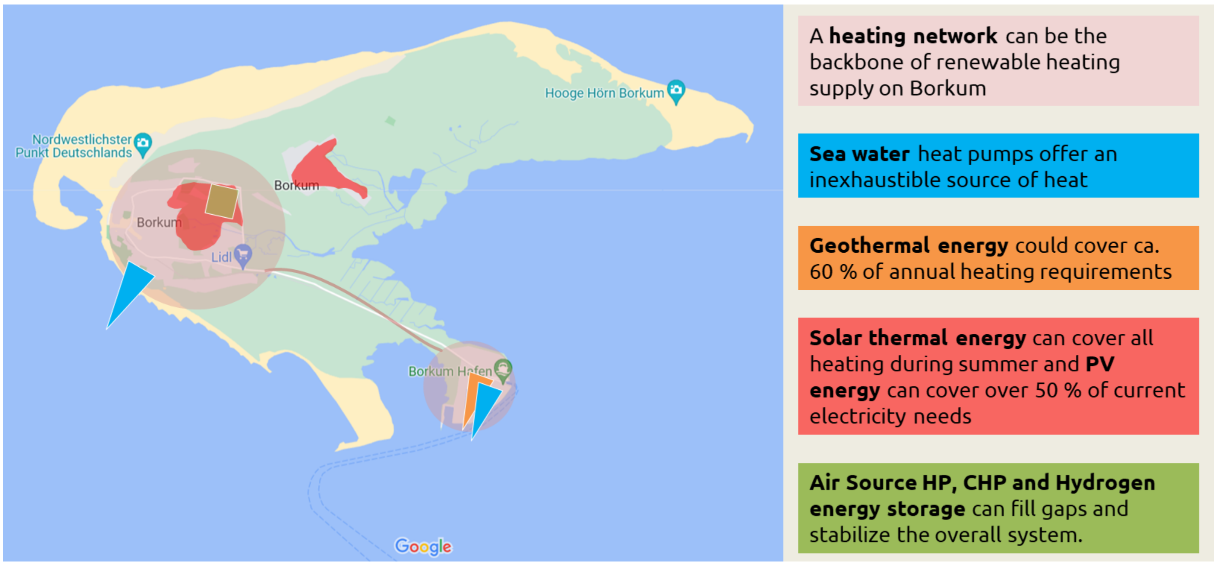

A **heating network** can be the backbone of renewable heating supply on Borkum

Sea water heat pumps offer an inexhaustible source of heat

Geothermal energy could cover ca. 60 % of annual heating requirements

Solar thermal energy can cover all heating during summer and **PV energy** can cover over 50 % of current electricity needs

Air Source HP, CHP and Hydrogen energy storage can fill gaps and stabilize the overall system.

Figure 2: Potential locations of renewable energy installations and their potential on Borkum.

Hence, it can be said that renewable energy technologies have great potential on Borkum. However, it is expected that renewable electricity consumption will likely increase by a factor of two to three due to expected electrification of road transport and partially also of the heating requirements. This will create a bottleneck; on the one hand it is quite clearly understood that this huge amount of electricity cannot come solely from sources on the island and on the other hand this will also mean that the current available sea power cable connecting Borkum with the mainland will be likely undersized for the future. The purchase of additional renewable energy from the mainland and upgrading the sea power cable seems to be unavoidable. Only in case of successful exploration of deep geothermal energy, the heating and electricity needs could be fully covered by Borkum on their own. However, feasibility of deep geothermal energy is yet to be confirmed and already explorative drills would mean an investment of several million euros and hence way too large of a project for a new renewable energy community to start with.

3 INTRODUCTION TO ENERGY COMMUNITIES

In this chapter a background of renewable energy communities with a focus on their implementation is discussed. The deliverable D7.3 “Infopack for citizen engagement”, which is publicly available on the ISLANDER webpage, goes into more detail concerning a general background.

Definition by the Renewable Energy – Recast to 2030 (RED II)[2]

Renewable energy community’ means a legal entity:

- which, in accordance with the applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed

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[2] https://joint-research-centre.ec.europa.eu/welcome-jec-website/reference-regulatory-framework/renewable-energy-recast-2030-red-ii_en

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by that legal entity;

- the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities;

- the primary purpose of which is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits.

According to the European Commission "energy communities organize collective and citizen-driven energy actions that help pave the way for a clean energy transition". In principle, it is a concept where citizens come together to invest in renewable energies with a focus on a benefit for their region.

In Germany, energy communities are legally defined in the upcoming updated renewable energy law in Germany (EEG 2023 (§ 3 No. 15)) with the term "citizens' energy communities" (BEG). The law, EEG, defines:

- Nr. of natural persons: at least 50 natural persons with voting rights
- Share of domestic natural persons: At least 75 percent of the voting rights are held
- Share of remaining participants: maximum of 25 percent of the voting rights are held by SMEs or local authorities. (SMEs: < 250 employees, < 50 million euros in turnover or < 43 million euros in total assets)
- Distribution of voting rights: No member or shareholder is allowed more than 10% of the voting rights
- Influence on decisions: Opportunity to influence decisions of the shareholders' meeting mandatory
- More: Rules apply if several actors join together “energy community of energy communities”

Together with the legal definition comes a set of benefits that citizen energy communities receive by law over other types of organizations or investors. The benefits are that some projects can be realized without a tendering process, which reduces efforts. For solar PV projects (ground-mounted or on built-structures) up to 6 MW can be installed without a tendering process. And for wind energy projects the maximum size is 18 MW. Additionally, grants for planning and permission of wind energy projects are expected in the future. But there are also some downsides to these benefits. Only one solar plant or a wind project can be realized once every five years. And there is still a lack of implementation of energy sharing as provided for in European law.

In the following figure, the characteristics of two possible legal forms for energy communities in Germany are presented side by side. The most common one is the cooperative (eG), it is safe and allows equal voting rights for all participants.

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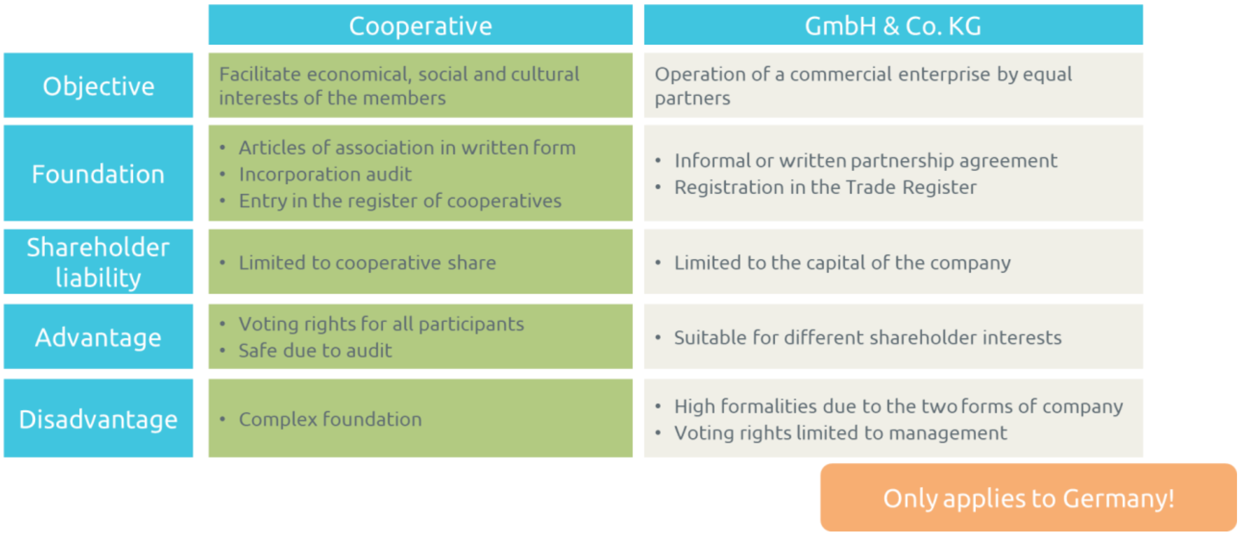

	Cooperative	GmbH & Co. KG
Objective	Facilitate economical, social and cultural interests of the members	Operation of a commercial enterprise by equal partners
Foundation	Articles of association in written form Incorporation audit Entry in the register of cooperatives	Informal or written partnership agreement Registration in the Trade Register
Shareholder liability	Limited to cooperative share	Limited to the capital of the company
Advantage	Voting rights for all participants Safe due to audit	Suitable for different shareholder interests
Disadvantage	Complex foundation	High formalities due to the two forms of company Voting rights limited to management

Only applies to Germany!

Figure 3: Legal forms for energy communities in Germany.

In Germany there are currently almost 1000 registered energy communities with a total of 220,000 members. The main business of energy communities in Germany is energy generation and distribution. 80% of RECs operate solar power, 30% operate wind power and 36% are involved in energy distribution. Other activities are not insignificant but are likely more dependent on local specificalities. More interesting facts on renewable energy communities can be found in the 2023 survey report of energy communities in Germany[3].

4 APPROACH AND SCOPE OF THE STUDY

Initially the transition pathway approach from the EU islands transition handbook 2020 distributed by the Clean energy for EU islands secretariat was applied[4]. The concept was used to understand the current situation of Borkum and define possible solutions. Island Transition Pathways describe strategies, barriers to overcome, important actors, and essential actions for the island's clean energy transition. The starting point is the island-wide vision on clean energy.

Exploring Island's transition pathways

Why?

The island transition pathways start from a vision and spell out options that exist for the island's clean energy future, with the aim of considering holistic energy scenarios. These options are structured and further developed in the transition pillars.

What?

In this phase, the island stakeholders are brought together to explore strategies for reaching their envisioned future. By identifying several storylines across different areas of intervention, several pathways towards this future vision are built.

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[3] Energiegenossenschaften 2020 (dgrv.de)

[4] Islands Transition Handbook | Clean energy for EU islands (europa.eu)

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How?

Analyzing the problem - “what is the transition challenge?” and discuss the features of the island vision. Identify and elaborate on the pillars of the transition - “which key areas will the transition address?”.

In a group effort together with mainly the technology providing partners of the ISLANDER project, the status of Borkum was listed in a pillar structure, which represents the pillar that the energy system of Borkum is built on. The result of this work is shown in the following figure.

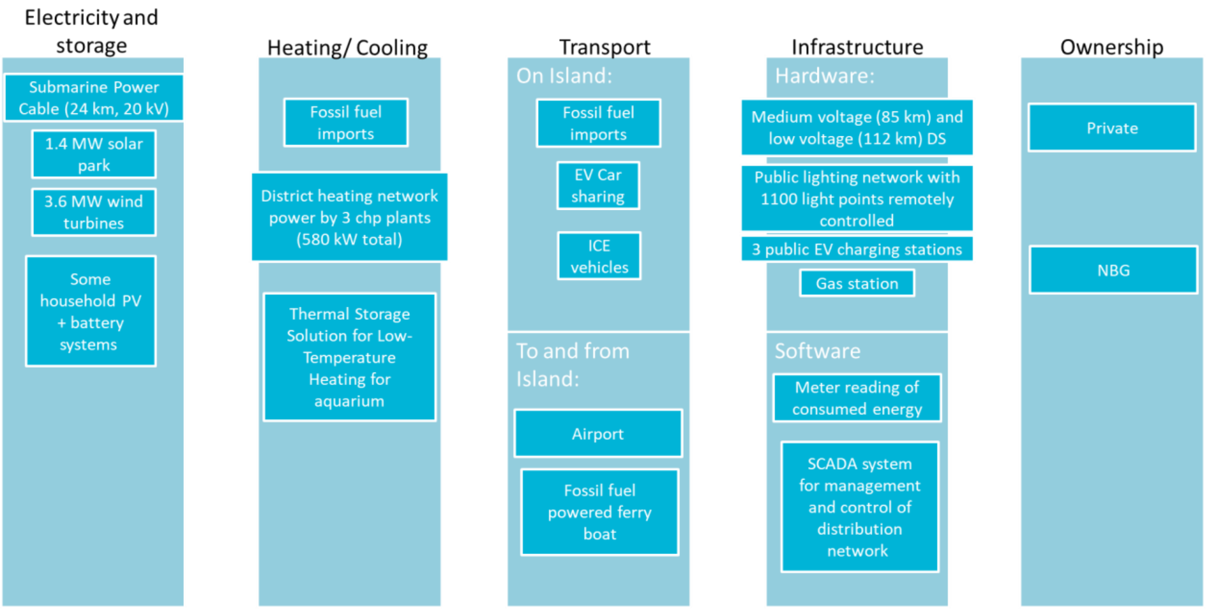

Figure 4: Pillar structure of Borkum's current energy system.

Then interventions were researched from the ISLANDER project and from the external study provided by NBG and again collected in the pillar structure as shown in the following figure.

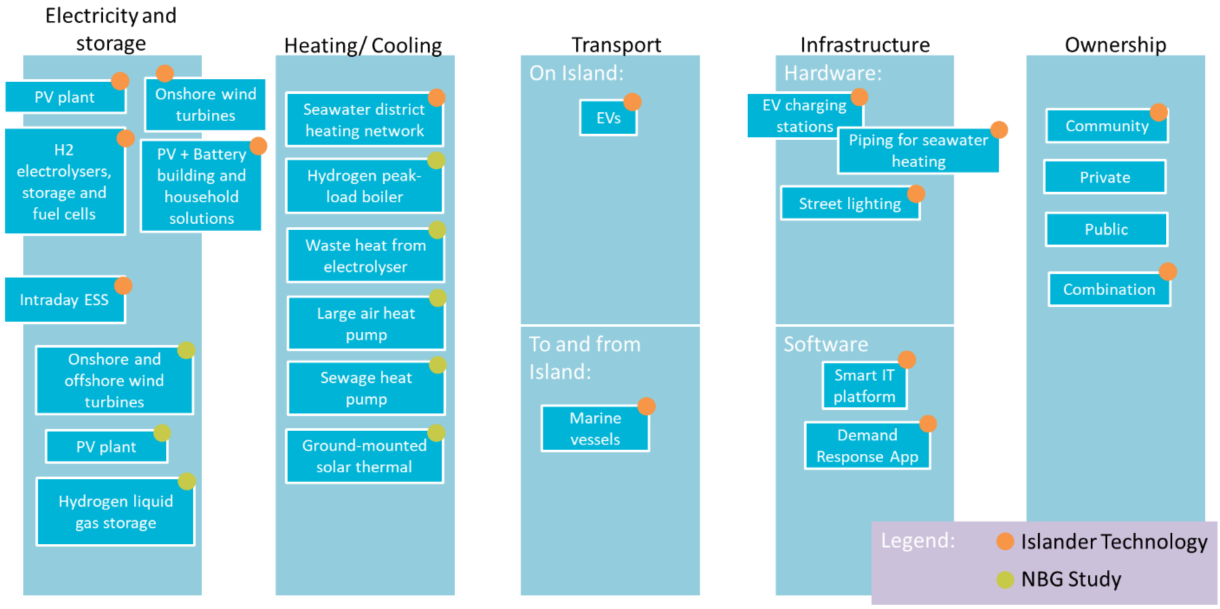

Figure 5: Potential interventions to decarbonize Borkum's energy system.

Subsequently a list of possible technologies for RECs was identified and prioritized by preliminary feasibility for REC to implement the solutions.

Table 1: Prioritized interventions to support Borkum's energy transition.

Priority	Technology	Comment
1	PV plants on commercial and public buildings	Easy to set up with plenty of successful examples
2	PV plants on private residential buildings	Easy to set up with plenty of successful examples
3	PV plants ground mounted	Easy to set up with plenty of successful examples but limited availability of land on Borkum
4	Sea water heat pump and district heating	Difficult to set up, but necessary for the transition on Borkum
5	Seasonal hydrogen storage solution	Difficult to set up, but potentially necessary for peak demand and stabilization
5	EV charging stations	Easy to set up, impact probably low
6	Alternative energy ferries (H2, battery)	Difficult to set up, but probably important impact

PV plants on commercial and private buildings or ground mounted are by far the most likely

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investment for any renewable energy community. All other technologies have some kind of drawback, which make them probably unsuitable for the creation of a REC. This can be high investment cost, early development stage or low impact. Ground mounted solar PV systems are not specifically examined in this study, but the building solutions can act as a benchmark to also drive this idea. However, it is known that there are limitations in available space on the island. One might also notice that onshore wind turbines are not listed as a possible option. Even though there is interest in having wind power produced on the island, the future of the windmills is still unclear since the German weather service has declared interest in installing a weather radar on the island. For this, the windmills would have to be removed and no additional wind power plants could be installed in a radius of 5 km around the weather station afterwards.

In the following chapters, the feasibility of selected individual technologies is described in greater detail. Fast response and intraday storage as well as EV charging stations are not further discussed in the following chapters. The fast response and intraday storage solution is mainly for grid stabilization and short-term peak demand. Hence connected business models are more closely connected to the utility company of Borkum and very likely no business for a REC. EV charging stations are a possible business for RECs but the impact of charging stations on the energy transition can be rated very low. The charging stations are always dependent on the provision of renewable energy and increased electrification of vehicles.

5 RESS HOUSEHOLD SOLUTION

5.1 Background and potential impact

The citizens of Borkum mostly live in one to two family homes. Only 17 % of the buildings contain three or more flats.

Table 2 - Family homes on Borkum[5].

Type of house	Number of houses
1-2 family homes	1,672
3 and more family homes	336
Total	2,008

Those 2,000 residential buildings offer the potential to be equipped with solar PV panels to produce renewable energy on Borkum. Currently there are 122 registered PV plants besides the SB Solarpark Borkum. Thereof 106 (in total 850 kWp) are owned by natural persons. Hence, only roughly 6 % of one to two family homes are equipped with solar power. This indicates that there is plenty of free roof area available that could be equipped with PV panels in the future and supply about a third of Borkum's current electricity demand.

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[5] https://www.stadt-borkum.de/city_info/display/dokument/show.cfm?region_id=347&id=412458

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5.2 Description of the RESS household solution of the ISLANDER project

Within the ISLANDER project, the RESS Household solution consists of the necessary equipment for a total of 30 households to allow nearly complete self-consumption via solar renewable energy sources. Therefore, such a system contains a Li-ion battery to store the surplus of energy generated. Figure 6 depicts the main components and the connections between them.

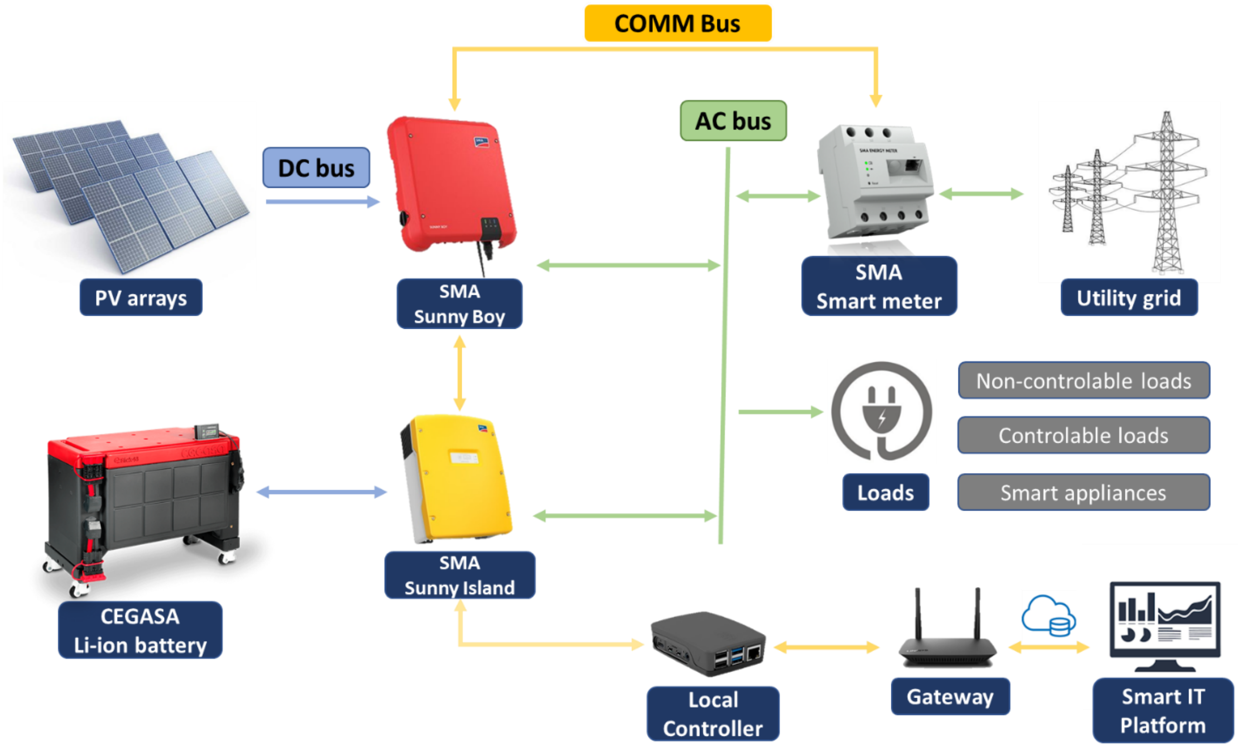

Figure 6: Main components of the RESS Household solutions.

As can be observed in the above figure, each installation is composed of the following:

- Photovoltaic solar panels installed on the roofs: these will transform the solar radiation falling upon the surface into electricity. The total power is 4 kWp per household.
- SMA Sunny Boy inverter: responsible for transforming the DC power produced by the solar panels into AC power so that it can be used by different appliances or loads.
- CEGASA Li-ion battery: it will store the surplus electricity in peak production moments and use it when necessary. The total capacity of the battery is 13.5 kWh.
- SMA Sunny Island inverter: responsible for the energy flow between the AC bus and the battery so that it can store the surplus of energy.
- SMA Energy Meter: this device provides accurate measures of both the incoming and outgoing energy for the whole household. This information is transferred to both SMA inverters for proper operation. This device also enables phase balancing, especially important for German households.
- Wiring, switches, and protections, among others, guaranteeing the correct operation and safety of the system.
- Controlling and monitoring devices in constant communication with the Smart IT platform to ensure the optimal performance of the distributed energy sources.

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The operation of the whole system is strongly dependent on the communication system, which is crucial to ensure the optimal performance of the RESS Household solutions. The local controller is constantly sending telemetries coming from all SMA elements to the smart IT platform. Such a platform uses this data, together with additional information (e.g., weather, consumption or electricity price), to decide the setpoints of the battery, i.e., how much it needs to charge or discharge at every instant. Combining this technology with the self-consumption solution deployed turns it into a smart and optimized renewable energy generation system.

In simple terms, the solution's objective is to reach net zero energy consumption households. Achieving this goal entails a positive impact on the consumers, as they will experience significant savings on their electricity bills. Furthermore, at a wider scope, the burden on the grid will be reduced during peak-demand periods, thus reducing the share of non-renewable energy sources usage at the regional level.

5.3 Main components and installation of equipment

In the following tables the main components of one of the RESS household solutions including their installation are listed together with their costs.

Table 3: RESS household solution list of main components and costs for one household.

Nr.	Component	Description of function	Design / Sizing	Nr. of units	Cost

Solar PV system:					
1	PV solar panel	Production of electricity	400-455 Wp	10 panels	1,000.00 €
2	SMA Sunny Boy inverter	Convert DC current from PV to AC	3 kW	1	897.00 €
3	SMA Smart Meter	Measurement of the active and reactive power, harmonics, etc.	N/A	1	300.10 €
	Subtotal solar PV				**2,179.10 €***

*: It has to be taken into account that the Islander consortium received a significant discount through bulk prices for some of the components since 30 household solutions were ordered at once. These prices might not be realizable for individual installations.

Battery storage system:					
4	Battery storage	Battery storage including control unit	13.5 kWh	1	4,298.00 €
5	SMA Sunny Island inverter	Convert DC current from batteries to AC	3,3 kW	1	2,183.00 €
6	Connection wiring	Connection between the different components of the system.	N/A	1	50.00 €
7	Raspberry Pi 4B	Communication between inverter and smart IT platform	8 GB RAM	1	200.00 €
	Subtotal Battery				**6731.00 €**

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Total System cost	8910.10 €

Table 4: RESS household solution installation work and costs.

Step	Description	Cost
	Solar PV system:	
1	Plastic tubes, arcs and channels mounting	Package offer
2	installation of the fire protection system	
3	DC wires from PV to inverter, AC wires inverter to grid	
4	Installation of structure and PV modules	
5	Deployment of inverters, batteries, and control systems	
6	Protections, energy meter, monitoring system etc.	
7	Network connection	
8	Documentation	
9	Grounding connection	
	Subtotal solar PV system	4,452 €
	Battery storage system:	
10	Mounting SMA Battery-inverter	250 €
11	Mount CEGASA Battery	280 €
	Subtotal Battery storage system	530 €
	Total installation costs	4,982 €

In the following table the ISLANDER RESS household solution costs are compared with values (also including installation and all materials needed to deploy the PV systems) found via web research on German websites. More details of this research can be found in Annex A. This comparison shows that costs of the ISLANDER PV system are similar to prices found via the web. Comparing the costs for battery storage solutions, the low costs of the ISLANDER solution stands out in comparison with the web research.

Table 5 – Cost comparison between the ISLANDER RESS household solution and costs found via web research.

Solar PV system	Specific costs
ISLANDER	1,657 €/kWp
Web research	1,167 – 1,838 €/kWp
Battery storage system	
ISLANDER	376 €/kWh

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Web research	700 – 1,200 €/kWh

5.4 Regulations

Besides the cost estimations, the regulations play a major role in determining the economic viability of the RESS household solutions. From ISLANDER's public deliverable D2.1 we already know that no building permits are required for PV systems on roofs or facades. Other conditions apply for ground-mounted systems. However, protection of historical buildings and adjacent buildings is important. A law for the protection of historical buildings is in place ("Niedersächsisches Denkmalschutzgesetz"[6]). This law should always be considered.

For solar PV systems the energy feed-in regulations are very important. They define the revenue a solar PV plant will make when electricity is fed to the grid. This tariff is guaranteed to be paid for 20 years when electricity is fed to the grid. For this the solar PV plant must be registered. The tariffs have been constantly updated in the past years. The current (2023) feed-in tariffs are listed in the following table. Care must be taken that the updated numbers are always used to define the business case.

Table 6: 2023 Energy feed-in regulations according to Germany's renewabewable energy law.[7]

	Fixed feed-in tariff	Bonus for 100 % feed-in[1]	Total for 100 % feed-in
≤ 10 kWp	8.2	4.8	13.0
≤ 40 kWp	7.1	3.8	10.9
≤ 100 kWp	5.8	5.1	10.9
≤ 400 kWp	5.8	3.2	9.0
≤ 1 MWp	5.8	1.9	7.7

[1]: 100 % meaning one full calendar year

For all values in Table 6: For electricity from solar energy systems installed exclusively on, at, or in a building or noise barrier. Other rules apply for ground-mounted and other PV systems.

Also, the values to be applied are subject to a yearly degression for new installations. They are reduced from February 1, 2024 and thereafter every six months for installations commissioned after that date by 1 percent compared with the values to be applied in the respective preceding period and shall be rounded to two decimal places. The unrounded values shall be used as the basis for calculating the amount of the values to be applied based on a renewed adjustment.

Taxes and tax benefits for solar PV systems

Relevant taxes for households with solar PV and battery storage systems

As of January 1, 2023, sales tax is usually no longer due on the purchase of a photovoltaic system and an associated electricity storage system. This tax is also known as the VAT. You now pay 0 instead of 19 percent VAT; the net and gross amounts on the invoice are identical. Legally, it is a so-called zero tax rate, for the buyer it is like a tax exemption.

The new rule applies from 2023 to the supply and installation (assembly) of a photovoltaic system including all components. This also includes an associated battery storage system, even

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[6] http://www.voris.niedersachsen.de/jportal/?quelle=jlink&query=DSchG+ND&psml=bsvorisprod.psml&max=true&aiz=true

[7] § 48 EEG 2023 - Einzelnorm (gesetze-im-internet.de)

if it is retrofitted to an existing PV system. You must meet the following requirements to be exempt from VAT:

1.) The photovoltaic system is installed on the roof of a residential building or in the immediate vicinity (carports, garages or a barn are included). Public and other buildings that serve the common good are also included.
2.) If, according to the market master data register, the output of the system is 30 kWp or less (kilowatt peak, which is the unit of measurement for the peak output of a PV system), the requirement is always automatically considered to be met.
3.) You yourself are the operator of the PV system, the invoice is issued in your name.
4.) The delivery and installation of the order (PV system and optional battery storage) may have begun in 2022 but must not have been completed until 2023.

The following rules apply for special circumstances:

- Balcony power plants: They are also called mini solar plants and are generally exempt from VAT.
- Renting PV systems: Renting a photovoltaic system is not exempt from tax. However, it depends on the details of the contract. For certain leasing or hire-purchase contracts, the 0 percent VAT does apply if you automatically become the plant owner at the end of the rental period. If the takeover of the plant is optional and makes economic sense at the same time, then this is also the case. This could be the case, for example, if the supplier gives you the plant for a symbolic price of 1 euro.
- Note: In such contracts, only the part of the rent that relates to delivery and installation is tax-privileged. Service work, on the other hand, is subject to regular VAT. The Federal Ministry of Finance in Germany has clarified in an official letter that it is recognized as a lump sum if 10 percent of the rent is declared as service and taxed.
- Mobile solar modules: They are used for camping, for example - the zero tax rate does not apply to these solar panels.

In general, the 0 percent sales tax on new PV systems has only advantages. You can become a so-called small business owner right from the start and therefore do not have to pay sales tax on the electricity generated. If you have installed your PV plant before 2023, other rules apply. However, since this deliverable is looking in the future it doesn’t cover this case.

When do you need to pay sales tax/VAT:

Even if the sales tax usually does not apply to the purchase of photovoltaic systems, there are essentially three cases from 2023 onwards in which you will still pay sales tax:

- You installed the PV system between 2018 and 2022, initially chose standard taxation and are waiting to be able to switch to the small business regulation.
- You install your PV system from 2023, but the system does not meet the criteria for exemption from VAT on purchase.
- Your total business turnover is so high that the small business rule does not apply to you and you are liable for VAT. The small business rule can be applied if the yearly turnover is equal to or lower than 22,000 €.

Additionally, small photovoltaic systems will be completely tax-free from 2022. And this is compulsory and not, as in the case of a hobby application, only in the case of a corresponding application. This applies to photovoltaic systems with a total installed gross capacity (according to the market master data register) on, at or in single-family houses (including roofs of garages and carports and other outbuildings) or non-residential buildings (e.g. commercial property, garage yard) of up to 30 kW (peak). Similar to the VAT exemption.

In addition, the tax exemption also applies to photovoltaic systems on, at or in other buildings.

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The draft law initially contained a different description, according to which use predominantly for residential purposes would have been required. This was changed at the suggestion of the federal states, so that photovoltaic systems on so-called "mixed buildings" are now also covered by the tax exemption. However, a maximum size of 15 kW (peak) (proportional gross output according to the market master data register) per residential and commercial unit must be observed. This particularly favors private landlords, condominium owners' associations, cooperatives and rental companies.

The tax exemption applies to the operation of several systems up to a maximum of 100 kW (peak). The 100 kW (peak) limit must be checked per taxpayer (natural person or corporation) or per joint venture. Hence, this also applies to energy cooperatives.

It can be assumed, though outside the scope of this study, that for private persons with solar PV installations larger than 30 kWp or larger than 100 kWp for the operation of several systems income tax must be paid on the earnings made in addition to the VAT paid on the energy sales or self-consumption.

Relevant taxes for energy communities

From the discussion above it became clear that for energy communities similar tax benefits apply as for private persons. Those are mainly:

1.) Individual solar PV systems on single family homes with a capacity of up to 30 kWp are tax free.
2.) Individual solar PV systems on mixed buildings with a capacity of up to 15 kWp per unit (e.g. per flat or per business) are tax free.
3.) 1.) and 2.) only apply if the total capacity of all owned solar PV systems have a maximum of 100 kWp.

With this new rule there are still some open questions being discussed if 1.), 2.) and 3.) don't apply. E.g. when the sum of all solar PV systems of an energy community exceeds 100 kWp, does the tax have to paid for all or only for the ones exceeding 100 kWp. Also, there are more cases, where the law is unclear, especially in cases of co-ownership. In general, the following tax rules for cooperatives and GmbH & Co. KGs apply.

Cooperatives

The corporate tax for cooperatives is 15.825 % (including the German solidarity tax of 5.5 % on top of the 15 % corporate tax). In addition, businesses must pay a trade tax, which is 3.5 % multiplied by lever that is dependent on the municipality. For Borkum this lever is 380 %. Hence the trade tax totals to 13.3 %. In total, cooperatives must pay income taxes on their earnings of 29.125 %. In the literature, usually the range of 30 – 33 % is mentioned for the income tax in general for cooperatives in Germany depending on the municipality where the business is located. This tax must be paid on the operating profits of the cooperative, after all costs have been deducted. In addition, for cooperatives there are no further tax allowances. Some exceptions exist for non-profit cooperatives and for cooperatives active in agriculture and forestry. But this is can be assumed to not apply to RECs and is beyond the scope of this deliverable.

GmbH & Co. KG

Same income taxes apply as for cooperatives, hence 29,125 % for Borkum. In addition, there is a 24,500 € tax allowance on the trades tax for the KG (can be deducted from the operating profits (but those can't get below zero) for tax calculation).

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Final note on taxes

This section does not aim to give general tax advice but wants to highlight an overview of the current situation. In any case it is advisable to consult a tax expert before any investment decisions are made. However, this overview can serve the information needed to estimate different cost benefit scenarios as presented in the sections below.

5.5 Simulation of cases for the RESS household solution

To increase understanding for the situation from a viewpoint of households and from a viewpoint of renewable energy communities, several cases were studied to generate results on energy production of the PV panels, estimation of self-consumption with and without a battery solution and the amount of energy fed into the grid. This information will then be used for economic calculations in the next step.

For the simulation of the household cases, a standard load profile from the Federal Association of Energy and Water Management (BDEW in Germany) was used and a yearly consumption of 1000 kWh was assumed.

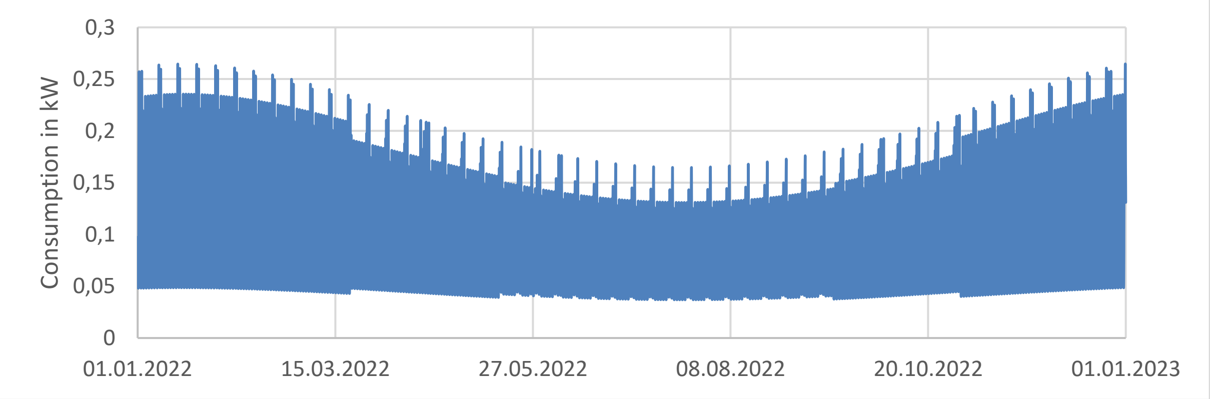

Figure 7: Yearly consumption pattern of standard household profile for a yearly consumption of 1000 kWh.

Technical parameters for the solar PV and battery storage system were taken from technical product data sheets for the equipment used in the ISLANDER RESS household solutions. In addition, it was assumed, that households have an average of 50 m² of free roof space. For the installation of the batteries, it was assumed that roughly 18 m³ is available in a room, e.g. in the basement where also the heating system of the household is present. This information is required for the estimation of maximum installable PV panels and batteries per household.

Technical parameter	Solar PV system	Battery storage system
Lifespan	25 years	1650 capacity cycles (one cycle = charge and discharge equal to the max capacity)
Aging rate	0.55 %	Assumed no aging within the 1650 cycles
Inverter efficiency	97 % (DC to AC)	95 % (Including charge and discharge)
Required space	5.5 m²/kWp	0.1 m³/kWh
Maximum space per household	50 m²	18 m³

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To generate the solar PV production curves, which is an input required for the simulation tool developed by Ayesa, the pvwatts calculator by the National Renewable Energy Laboratory (NREL) was used[8]. The following assumptions regarding the parameters for the solar PV system were taken:

- Requested Location:	Borkum
- Location:	GRONINGEN, NETHERLANDS
- Module Type:	Standard
- Array Type:	Fixed (open rack)
- Array Tilt (deg):	20
- Array Azimuth (deg):	180
- System Losses (%):	14.08
- DC to AC Size Ratio:	1.2
- Inverter Efficiency (%):	97

Finally, this information was used by AYESA in their open-source IT tool for the optimal design of island's energy systems to estimate the needed input for the economic calculations. Besides the costs listed in chapter 5.3, the fixed feed-in tariffs listed in chapter 5.4 were used for the simulation. Finally, an energy price of 0,39 €/kWh (incl. monthly fees) were used based on the current pricelist by the utility company of Borkum.

For the simulation, three general cases have been studied on top of the different financial inputs from the ISLANDER project and the web research:

1.) Full optimization: Here the goal was to let the algorithm calculate the economically optimal solar PV and battery capacities.
2.) ISLANDER RESS household solution system size: This is to check the system capacities chosen for the ISLANDER project.
3.) PV capacity cost optimized and battery capacity equals 1 kWh: Equal capacities (solar PV kWp = battery storage kWh) is an often-seen approach for a recommended system size. However, if financially viable, the solver was given the choice to increase the solar PV capacity.

It must be noted that the simulation aims at minimizing costs for the individual cases. Hence some modifications to financials had to be done in order to "force" some outcomes, e.g. simulation a system with a certain capacity. The results with respect to economics will be discussed in the following chapters. In the following table the results from the open-source IT tool are shown.

Case	Case ID	Financials		Solar PV capacity	Battery storage capacity	Battery useful life	Self consumption		Electricity fed to grid
				kW	kWh	a	kWh/a	%	kWh/a
Full optimization	1	ISLANDER		0.53	-	-	353	35	227
	2	Web research	Min	9	-	-	558	56	9,188
	3		Max	1	-	-	426	43	680
ISLANDER solution	4	ISLANDER		4	13.5	51.3	532	98	3,365
	5	Web research	Min						
	6		Max						
PV optim. and battery	7	ISLANDER		1	1	7.2	423	65	431
	8	Web	Min	9	1	5.2	557	87	8,873

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[8] PVWatts Calculator (nrel.gov)

cap. = 1 kWh	9	research	Max	1.35	1	6.6	452	70	754

Conclusions from the case study:

- The optimal solution is highly dependent on the financial inputs. More general rules to apply will be developed in the following chapters.
- Maximum solar PV capacity for a 50 m² roof is 9 kWp.
- Maximum direct self-consumption from PV is ca. 56 % of the total electricity used.
- Maximum self-consumption can be increased to 98 % using battery storage and the battery storage size suggested by the ISLANDER RESS household solution is suitable for this purpose.
- Electricity produced by the PV is fed/sold to the grid during times where there is no usage for it in the household. Depending on the case this share of sold energy is quite substantial and is therefore always of importance for the cost benefit analysis.

5.6 Cost benefit analysis

5.6.1 Approach to the cost benefit analysis

The cost benefit analysis was performed by developing several parameters to judge economic viability of the different cases studied in the chapter above. The parameters discussed in the following are only described on a high level here. At this point it is referred to available literature for the calculation of these parameters. The parameters developed are:

- **Net present value (NPV)**: The net present value is the difference between the present value of cash inflows and the present value of cash outflows over a period. The present value takes an inflation adjusted discount rate into account. This discount rate makes it possible to compare cash flows at different points in time. It includes the weighted average cost of capital (or opportunity cost depending on the source of money), the general inflation rate, and the energy price inflation rate. A positive NPV indicates economic viability.
- **Internal rate of return (IRR)**: The internal rate of return (IRR) is the annual rate of growth that an investment is expected to generate. If the NPV is zero, the IRR is equal to the discount rate used for the NPV calculation.
- **Payback period**: The payback period indicates the time it takes to break even, hence the investment has been fully returned by the profits generated through the project. It can be calculated by dividing the costs of an investment by the annual profit. There is a difference between a discounted payback period and a "simple" payback period. A discounted payback period is larger than a simple payback period since it takes the changing value of cash flows over time into consideration. For this study, the "simple" payback period is reported. It can usually be used to indicate the risk of an investment. A shorter payback period indicates lower risk due to uncertainty of the future. It is especially important for risk averse investors.
- **Levelized cost of energy (LCOE)**: The LCOE, sometimes also named levelized cost of electricity or the levelized energy cost (LEC), is used to assess and compare different methods of energy production. It can be thought of as the average total cost of building and operating the asset per unit of electricity generated over the assumed lifetime of the asset. In other terms, it can also be thought of as the average minimum price at which the electricity needs to be sold to offset the total costs of production over its lifetime. Calculating the LCOE is related to the concept of assessing a project's net present value. Similar to using NPV, the LCOE can be used to determine whether a project will be a worthwhile venture.

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Several assumptions had to be made to estimate the financial parameters described above. Those are listed in the following table:

Parameter	Value	Assumption
Weighted average cost of capital/ opportunity cost	6 %	Energy projects are usually between 4 and 10 %. Additionally, 6 % is a good estimate for general capital market growth in the past years.
European inflation rate	2.19 %	European average inflation rate over the past 30 years.
Energy price inflation rate	2 %	Energy prices are usually growing faster than inflation. On average it has been growing about 2 % more than inflation in the past years.
Inflation adjusted discount rate	2.26 %	This value is the resulting discount rate from the values above. It also takes the aging rate of the solar PV panels into account.

Finally, maintenance and operation costs per year (including insurance) were estimated to be 1 % of the initial investment (equipment and installation) per year. This percentage was used as estimate based on information found through web research.

5.6.2 From the viewpoint of households

In the cost benefit analysis studied in this section it was checked whether the investment in the RESS household solutions and the cases described above are economically viable for individual households. Therefore, it only aims to understand the viewpoint of households and whether they might be interested to install the solutions by themselves.

To understand the viewpoint of households, two cases were studied:

1. Self-consumption using solar PV and battery storage where available, and
2. Feeding all electricity into the grid.

The following table lists the economic results for the first case of self-consumption.

Table 7: Economic viability of the studied cases for self-consuming households.

Case	Case ID	Financials		PV & Bat. capacity	Self cons.	Total invest	NPV	IRR	Payback period	LCOE
				kW / kWh	%	€	€	%	A	€/kWh
Full optimization	1	ISLANDER		0.53 / -	34	879	1,392	15.3	6.2	0.11
	2	Web research	Min	9 / -	54	10,505	2,834	4.9	12.6	0.08
	3		Max	1 / -	41	2,848	126	2.7	15.3	0.19
ISLANDER solution	4	ISLANDER		4 / 13.5	92	13,892	-6.116	-3.2	>20	0.24
	5	Web research	Min			14,119	-6,378	-3.3	>20	0.24
	6		Max			27,590	-21,999	-10.6	>20	0.48
PV optim. and battery cap. = 1 kWh	7	ISLANDER		1 / 1	62	3,145	734	4.6	12.9	0.22
	8	Web research	Min	9 / 1	83	13,176	1,108	3.1	14.7	0.10
	9		Max	1.35 / 1	67	7,465	-3,569	-3.7	>20	0.38

The following table shows the results of the economic calculations for the second case, where all electricity is fed to the grid in order to receive a higher feed-in tariff. Hence, all the following

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cases are without batteries and without self-consumption.

Table 8: Economic viability of feeding all energy produced to the grid.

Case	Case ID	Financials		PV capacity	Self cons.	Total invest	NPV	IRR	Payback period	LCOE
				kW	%	€	€	%	a	€/kWh
Full optimization	1	ISLANDER		0.53	0	879	148	3.8	13.7	0.11
	2	Web research	Min	9	0	10,505	7,426	8.7	9.3	0.08
	3		Max	1	0	2,848	-1,075	-2.3	>20	0.19
ISLANDER solution	4	ISLANDER		4	0	6.631	1,025	3.8	13.7	0.11
	5	Web research	Min			4,669	3,300	8.7	9.3	0.08
	6		Max			11,390	-4,493	-2.5	>20	0.20
PV optim. and battery cap. = 1 kWh	7	ISLANDER		1	0	1.658	256	3.8	13.7	0.11
	8	Web research	Min	9	0	10,505	7,426	8.7	9.3	0.08
	9		Max	1.35	0	3,830	-1,511	-2.5	>20	0.20

5.6.3 From the viewpoint of a renewable energy community

In this section the viewpoint of renewable energy communities is taken by studying three different business models. The three models are:

1. Rent roof from households and feed-in of all energy produced using only solar PV systems.
2. Landlord tenant model
    a. Energy sales from Landlord (REC) to tenant (household) using only solar PV systems.
    b. Energy sales from Landlord (REC) to tenant (household) using solar PV systems and battery storage.

Rent roof from households and feed-in of all energy produced using only solar PV systems

In this business model the renewable energy community pays a rent for the roof to the household. The household receives a yearly rent and the renewable energy community installs and operates the solar PV system. In this scenario, it was assumed that all energy produced by the PV panels is fed to the grid. During the process of the calculations the rent was adjusted to make economic sense. A rent per m² roof per year of 6 €/m² (space requirement is 5.5 m²/kWp of solar PV panels) was found to be a feasible solution for both parties. The levelized cost of energy is not included in the following tables since it doesn't change in comparison to Table 7 and Table 8 from the previous section.

Table 9: Economic viability of renting household roofs and selling electricity to the grid from the viewpoint of renewable energy communities.

Case	Case ID	Financials		PV capacity	Household savings		Total invest	NPV	IRR	Payback period
				kW	€/a	% of energy bill	€	€	%	a
Full optimization	1	ISLANDER		0.53	17	4%	879	-131	0.5	19
	2	Web research	Min	9	297	76%	10,505	2,688	4.8	12.7
	3		Max	1	33	8%	2,848	-1,602	-5.1	>20
ISLANDER	4	ISLANDER		4	132	34%	6.631	-1,081	0.5	19

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solution	5	Web research	Min				4,669	1,195	4.8	12.7
	6		Max				11,390	-6,599	-5.4	>20
PV optim. and battery cap. = 1 kWh	7	ISLANDER		1	33	8%	1.658	-270	0.5	19
	8	Web research	Min	9	297	76%	10,505	2,688	4.8	12.7
	9		Max	1.35	44	11%	3,830	-2,219	-5.4	>20

Landlord tenant model

In this business model, the renewable energy community installs solar PV and battery storage systems in the households. It then sells the produced and stored energy to the household for a cheaper price in comparison to the utility company. On the other hand, the maximum price for electricity is set to 90 % of the local electricity price, if the goal is to also utilize the subsidy listed below. This model is called landlord to tenant model and is usually used to give landlords who rent out flats an option and subsidies to include renewable energies in their buildings.

The electricity produced by the solar PV is not supplied using the public power grid and can therefore be offered at particularly low prices: Grid usage fees, concession fees and electricity tax do not apply.

Those who supply tenants with electricity conclude a tenants' electricity contract with the residents involved for the full supply of electricity. To ensure security of supply around the clock, the solar power is supplemented by grid power when there is not enough direct renewable energy available. Those who purchase tenant electricity can still change their mind and, like other electricity customers, switch suppliers.

For photovoltaic systems commissioned in 2023 and 2024, the tenant electricity subsidies are listed in the following table.

Table 10: Landlord to tenant subsidies.

Solar PV capacity	Landlord tenant subsidy
up to 10 kWp	2.68 cent/kWh
10 – 40 kWp	2.48 cent/kWh
Up to 1 kWp	1.67 cent/kWh

This subsidy explicitly allows tenant electricity to be supplied by third parties: This makes contracting models possible. This enables homeowners' associations or private landlords to implement tenant electricity projects without having to have their own expertise in the energy market. The following graphic illustrates the contractual agreements and the flow of electricity for this business model. In this scheme, the renewable energy community could be both, Operator and Power distributor.

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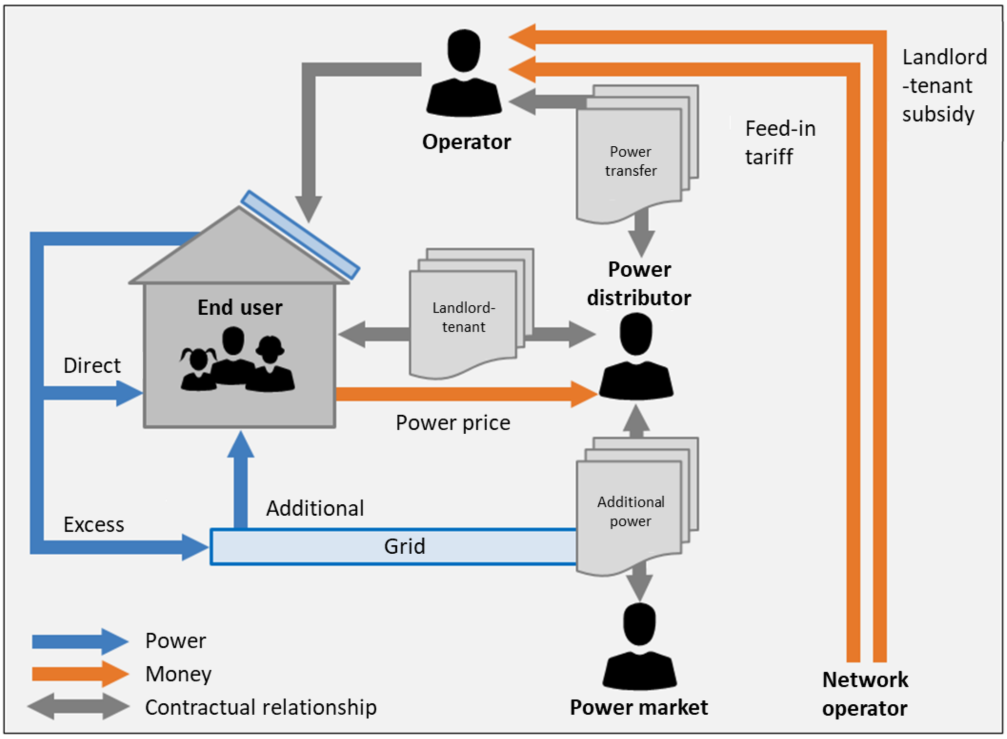

Figure 8: Landlord to tenant business model.

Energy sales from Landlord (REC) to tenant (household) using only solar PV systems

In this case it was assumed that only solar PV is installed. A battery storage is not included here. Due to economic feasibility, the electricity price that results for the households can be as low as 0.23 €/kWh which includes the 19 % sales tax and all other fees for the portion of energy bought from the grid. Accordingly, the households can save up to 41 % on their electricity bill. The following table shows the results of the economic calculations.

Table 11: Economic viability of the landlord to tenant model if only solar PV panels are installed.

Case	Case ID	Financials		PV capacity	Household savings		Total invest	NPV	IRR	Payback period
				kW	€/a	% of energy bill	€	€	%	a
Full optimization	1	ISLANDER		0.53	107	28%	879	154	4.0	13.6
	2	Web research	Min	9	158	41%	10,505	540	2.8	15.2
	3		Max	1	66	17%	2,848	-748	-0.7	>20
ISLANDER solution	4	ISLANDER		4	114	29%	6.631	-1,542	-0.4	>20
	5	Web research	Min		151	39%	4,669	401	3.1	14.7
	6		Max		80	20%	11,390	-6,253	-4.9	>20
PV optim. and battery cap. = 1 kWh	7	ISLANDER		1	128	33%	1.658	-35	2.0	16.3
	8	Web research	Min	9	158	41%	10,505	513	2.8	15.2
	9		Max	1.35	68	17%	3,830	-1,359	-1.9	>20

Energy sales from Landlord (REC) to tenant (household) using solar PV systems and battery storage

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In this case also battery storage was assumed. Some scenarios were left out since they do not include batteries. Due to low economic viability found in this case, the price for the tenant was set as the maximum of 90 % of the energy price from the grid. Hence, the resulting electricity price for the households was assumed to be 0.35 €/kWh and household savings are limited to 10 %.

Table 12: Economic viability of the landlord to tenant model using solar PV and battery storage.

Case	Case ID	Financials		PV & Bat. capacity	Household savings		Total invest	NPV	IRR	Payback period
				kW / kWh	€/a	% of energy bill	€	€	%	a
Full optimization	1	ISLANDER		Does not include battery solution.						
	2	Web research	Min							
	3		Max							
ISLANDER solution	4	ISLANDER		4 / 13.5	39	10	13,892	-6,772	-3.9	>20
	5	Web research	Min		39	10	14,119	-7,035	-4.1	>20
	6		Max		39	10	27,590	-22,655	-11.3	>20
PV optim. and battery cap. = 1 kWh	7	ISLANDER		1 / 1	39	10	3,145	-1,751	-5.0	>20
	8	Web research	Min	9 / 1	39	10	13,176	-125	2.2	16.1
	9		Max	1.35 / 1	39	10	7,465	-5,768	-9.8	>20

5.7 Conclusion and recommendation for household solutions

The results of the 5 business models discussed are summarized in the following table. Only IRR and self-consumption is listed in this table to indicate economic viability and relevance to Borkum's 2030 goal.

Table 13: Results of IRR and self-consumption (IRR/Self consumption in %) summary for the 5 business models studied (LT = Landlord to tenant).

Case	Case ID	Financials		PV & Bat. capacity	Household		Renewable Energy Community		
				kW / kWh	Self cons.	100% feed-in	100% feed-in	LT only PV	LT PV and bat.
Full optimization	1	ISLANDER		0.53 / -	15.3 / 34	3.8 / 0	0.6 / 0	4.0 / 34	-
	2	Web research	Min	9 / -	4.9 / 54	8.7 / 0	4.8 / 0	2.8 / 54	-
	3		Max	1 / -	2.7 / 41	-2.3 / 0	-5.1 / 0	-0.7 / 41	-
ISLANDER solution	4	ISLANDER		4 / 13.5	-3.2 / 92	3.8 / 0	0.6 / 0	-0.4 / 51	-3.9 / 92
	5	Web research	Min		-3.3 / 92	8.7 / 0	4.8 / 0	3.1 / 51	-4.1 / 92
	6		Max		-10.6 / 92	-2.5 / 0	-5.4 / 0	-4.9 / 51	-11.3 / 92
PV optim. and battery	7	ISLANDER		1 / 1	4.6 / 62	3.8 / 0	0.6 / 0	2.0 / 34	-5.0 / 62
	8	Web	Min	9 / 1	3.1 / 83	8.7 / 0	4.8 / 0	2.8 / 54	2.2 / 83

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cap. = 1 kWh	9	research	Max	1.35 / 1	-3.7 / 67	-2.5	-5.4	-1.9 / 41	-9.8 / 67

In general, solar PV to some degree is always economically viable. Adding battery storage increases self-consumption but decreases economic viability. Highest economic viability can be achieved by minimizing electricity fed to the grid, since the LCOE is barely covered by the feed-in tariff. This can be seen for case 1 with a very small solar PV system of only 0.53 kWp (in relation to the yearly consumption of 1,000 kWh) is economically viable even for moderate high investment costs (Case 1 with ISLANDER financials). Additionally, it achieves already 34 % of self-consumption with what you can call minimal effort and investment. It was also found that 1,000 €/kWh for battery storage or higher, as found through web research, is economically not viable. Battery storage is only economically viable for the significantly cheaper batteries in case of the ISLANDER project financials (376 €/kWh) and in case of the self-consumption from the viewpoint of the households. In this case 7, high self-consumption (62 %) combined with economic viability was found. For case 8, higher self-consumption of 83 % was achievable with minimal economical loss. Other economic viable cases leave out the battery. Only using solar, a self-consumption of up to 54 % is achievable in those cases with maximized solar PV capacity.

Recommendation towards renewable energy communities:

1.) All business models with solar PV system prices of 1,167 €/kWp and without battery storage were found to be economically viable.
2.) With minimal effort and investment solutions (case 1) self-consumption of 34 % can be achieved with great economic viability.
3.) Renting roof from private homes, installing solar PV systems, and feeding all produced electricity into the grid can be a worthwhile business if investment costs can be kept low. Additionally, the households can save significantly in relation to their energy bills (in our case up to 41 %). A rent of ca. 6 € per m² roof and year was found to be a feasible value for both parties.
4.) For high self-consumption, very large PV systems and battery storage is necessary. In this case, the overall business is more price sensitive and keeping costs low is of even higher priority.
5.) Finally, it must be noted that those are also attractive solutions for households to pursue by themselves with generally better economics. Special focus should be placed on households that are risk averse and shy away from the initial investment. Another strategy could be to offer a solution that is very comfortable and reduces household input, interactions, and responsibilities as much as possible. Chances are that for some it is just not as relevant as for others, but they don't mind supporting if the work on their end is kept to a minimum.

6 RESS BUILDING SOLUTIONS

6.1 Background and potential impact

In addition to the private households, there are roughly 1,000[9] commercially used buildings. About 80 % of these are hotels and other housings used to accommodate tourists visiting the

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[9] https://www.stadt-borkum.de/city_info/display/dokument/show.cfm?region_id=347&id=412458

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island. The remaining part is roughly equally split between retail, restaurants, and workshops. In addition to the commercially used buildings, there are several public buildings that might also be of interest for the RESS building solution. Those can include schools, community centers, libraries, information centers, government buildings, and public housing. It can be assumed that roughly another third of Borkums current electricity demand could be covered by PV installations on rooftops of commercial and public buildings.

6.2 Description of the RESS Building solution of the ISLANDER project

The overall system of the RESS building solution uses the same components as the RESS household solution. Therefore, it is referred to chapter 5.2 for details on the system and how the components interact. The main difference is that the building solutions have higher numbers of the individual components (PV panels and battery storage modules) or components with larger capacities. Another difference and specific of the building solutions of the ISLANDER project is a multi-stage converter that is able to convert electricity from AC to DC or vice versa for both the battery storage and the solar PV system at the same time. This multi-stage converter is being developed by partner Zigor within the ISLANDER project.

6.3 Main components and installation of equipment

In the following tables the main components of the RESS building solution including their installation are listed together with their costs.

Table 14: RESS household solution list of main components and their costs.

Nr.	Component	Description of function	Design / Sizing	Nr. of units	Cost
Solar PV system:					
1	PV solar panel	Production of electricity	400-455 Wp	50	5,000.0 €
2	Zigor multi-stage converter	Convert DC current from solar PV panels to AC	30 kVA	0.5	7,000.0 €
3	Raspberry Pi 4B	Communication between inverter and smart IT platform	8 GB RAM	1	200.0 €
4	Smart Meter	Measurement of the active and reactive power, harmonics, etc.	N/A	1	400.0 €
	Subtotal solar PV				**12,600.0 €**
Battery storage system:					
5	Battery storage	Battery storage including control unit	81 kWh	1	30,005.8 €
6	Zigor multi-stage converter	Convert DC current from batteries to AC	30 kVA	0.5	7,000.0 €
	Subtotal Battery				**37,005.8 €**

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Total System cost	**49,605.8 €**

Table 15: RESS household solution installation work and costs.

Step	Description	Duration	Cost
	Solar PV system:		
1	Plastic tubes, arcs and channels mounting		988.87 €
2	installation of the fire protection system		1,846.33 €
3	DC wires from PV to inverter, AC wires inverter to grid		790.67 €
4	Installation of structure and PV modules		23,736.67 €
5	Deployment of inverters and control systems		691.20 €
6	Protections, energy meter, monitoring system etc.		1,782.77 €
7	Network connection		70.00 €
8	Documentation		279.97 €
9	Grounding connection		131.50 €
	Subtotal solar PV system		**30,317.98 €**
	Battery storage system:		
10	Mounting inverter		146.67 €
11	Mount CEGASA Battery		566.67 €
	Subtotal Battery storage system		**713.33 €**
	Total installation costs		**31,031.31 €**

In the following table the ISLANDER RESS building solution costs are compared with values (also including installation and all materials needed to deploy the PV systems) found via web research on German websites. More details of this research can be found in Annex A.

The ISLANDER PV system is around twice as expensive as prices found via the web for larger scale installations. It is also the case that costs for installation and mounting materials is much higher for the ISLANDER project. The costs for the main components are about equal. Again, the low price of the battery solution in the ISLANDER case in comparison with the web research must be mentioned. Both facts must be considered when preparing the cost benefit analysis. The costs for the ISLANDER project are expected to show differences due to the research nature of the project. The prices found via web research can be assumed to be more important for building a possible business case.

Table 16 – Cost comparison between the ISLANDER RESS household solution and costs found via web research.

Solar PV system	Specific costs
ISLANDER	2,145 €/kWp
Web research	733 – 1379 €/kWp

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Battery storage system	
ISLANDER	466 €/kWh
Web research	700 – 1,200 €/kWh

6.4 Simulation of cases for the RESS building solution

The approach for the case studies for the RESS building solutions is similar as for the RESS household solutions. The viewpoint of buildings and the viewpoint of renewable energy communities is considered. Several cases were studied to generate results on energy production of the PV panels, estimation of self-consumption with and without a battery solution and the amount of energy fed into the grid. This information will then be used for economic calculations in the next step.

For the simulation of the building cases, load profiles of three different business from Borkum were used. The businesses chosen are a hotel with a yearly consumption of 228504 kWh, a grocery store with a yearly consumption of 212820 kWh and a restaurant with a yearly consumption of 46728 kWh. The yearly profiles for the three businesses are shown in the following graphs.

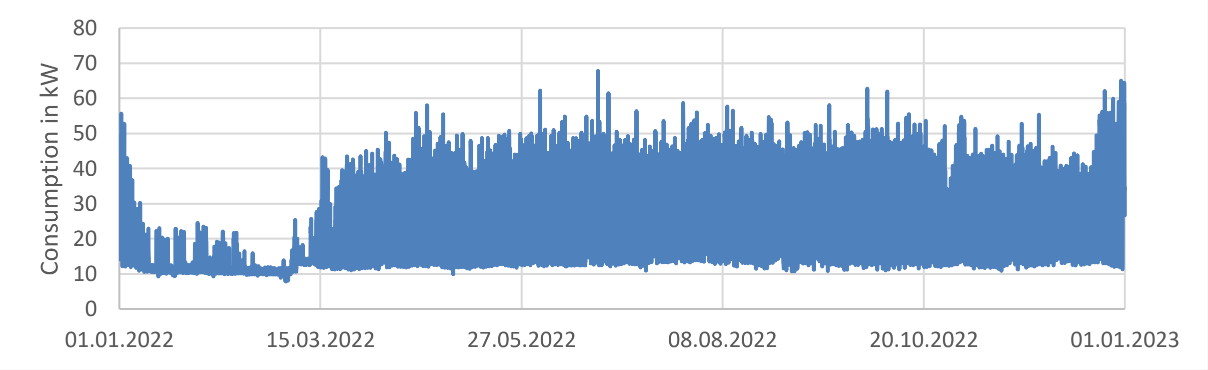

Figure 9: Yearly consumption pattern of the exemplary hotel on Borkum.

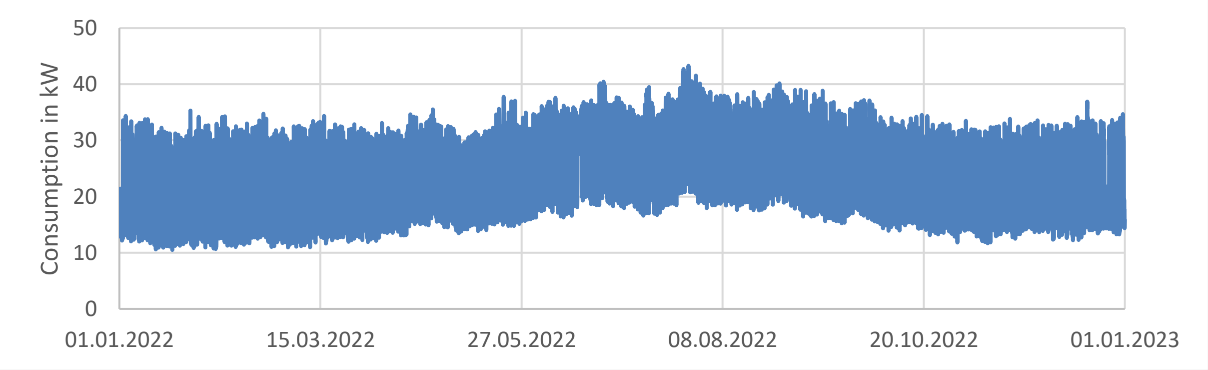

Figure 10: Yearly consumption pattern of the exemplary grocery store on Borkum.

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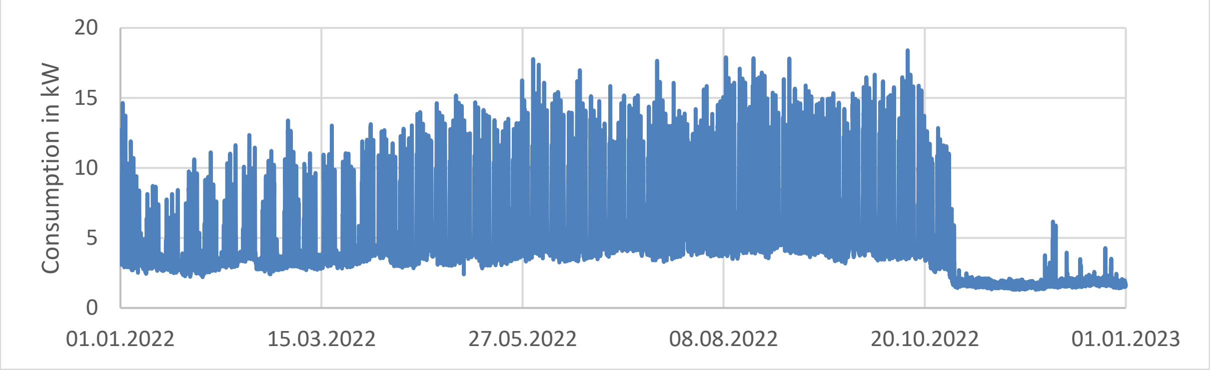

Figure 11: Yearly consumption pattern of the exemplary restaurant on Borkum.

The assumptions for the solar PV and battery storage system were taken from technical product data sheets for the equipment used in the ISLANDER RESS household solutions. In addition, it was assumed, that the buildings have the following free roof space available: Hotel: 880 m², Grocery store: 550 m², Restaurant: 100 m². For the installation of the batteries, it was assumed that roughly 18 m³ is available in a room, e.g. in the basement.

As for the household solution, to generate the solar PV production curves, which is an input required for the simulation tool developed by Ayesa, the pvwatts calculator by the National Renewable Energy Laboratory (NREL) was used[10].

Finally, this information was used by AYESA in their open-source IT tool for the optimal design of island's energy systems to estimate the needed input for the economic calculations. Besides the costs listed in chapter 6.3, the fixed feed-in tariffs listed in chapter 5.4 were used for the simulation. Finally, an energy price of 0,245 €/kWh (incl. monthly fees) were used based on the current pricelist by the utility company of Borkum.

For the simulation, three general cases have been studied on top of the different financial inputs from the ISLANDER project and the web research:

1. Full optimization: Here the goal was to let the algorithm calculate the economically optimal solar PV and battery capacities.
2. ISLANDER RESS household solution system size: This is to check the system capacities chosen for the ISLANDER project.
3. PV capacity cost optimized and battery capacity equals 100 kWh for the hotel and the grocery store and 20 kWh for the restaurant: Equal capacities (solar PV kWp = battery storage kWh) is an often-seen approach for a recommended system size. However, if financially viable, the solver was given the choice to increase the solar PV capacity.

It must be noted that the simulation aims at minimizing costs for the individual cases. Hence some modifications to financials had to be done in order to "force" some outcomes, e.g. simulation a system with a certain capacity. The results with respect to economics will be discussed in the following chapters. In the following table the results from the open-source IT tool are shown.

Table 17: Case study results for the hotel on Borkum.

Case	Case ID	Financials	Solar PV capacity	Battery storage capacity	Battery useful life	Self consumption		Electricity fed to grid
			kW	kWh	a	kWh/a	%	kWh/a

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[10] PVWatts Calculator (nrel.gov)

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Full optimization	1	ISLANDER		146	0	-	92,923	40.7	60,388
	2	Web research	Min	170			97,854	42.8	80,722
	3		Max	170			97,854	42.8	80,722
ISLANDER solution	4	ISLANDER		20	81	-*	21,091	9.2	0
	5	Web research	Min						
	6		Max						
PV optim. and battery cap. = 100 kWh	7	ISLANDER		144	100	7.7	132,649	58.1	37,693
	8	Web research	Min	170		6.9	142,996	62.6	57,493
	9		Max	170		6.9	142,996	62.6	57,493

*Battery storage system was not used by the open-source IT tool.

Table 18: Case study results for the grocery store on Borkum.

Case	Case ID	Financials		Solar PV capacity	Battery storage capacity	Battery useful life	Self consumption		Electricity fed to grid
				kW	kWh	a	kWh/a	%	kWh/a
Full optimization	1	ISLANDER		106	0	-	76,318	35.9	35,030
	2	Web research	Min						
	3		Max						
ISLANDER solution	4	ISLANDER		20	81	-*	21,091	9.9	0
	5	Web research	Min						
	6		Max						
PV optim. and battery cap. = 100 kWh	7	ISLANDER		106	100	9,3	109,676	51.5	17,891
	8	Web research	Min						
	9		Max						

*Battery storage system was not used by the open-source IT tool.

Table 19: Case study results for the restaurant on Borkum.

Case	Case ID	Financials		Solar PV capacity	Battery storage capacity	Battery useful life	Self consumption		Electricity fed to grid
				kW	kWh	a	kWh/a	%	kWh/a
Full optimization	1	ISLANDER		20	0	-	15,692	33.6	5,321
	2	Web research	Min						
	3		Max						
ISLANDER solution	4	ISLANDER		20	81	24.5	26,105	55.9	19
	5	Web research	Min						
	6		Max						
PV optim. and battery cap. = 20 kWh	7	ISLANDER		20	20	10.2	21,791	46.6	2,189
	8	Web research	Min						
	9		Max						

Conclusions from the case study:

- The optimal solution is highly dependent on the financial inputs. More general rules to apply will be developed in the following chapters.
- Maximum direct self-consumption from PV is ca. 33 - 43 % of the total electricity used by the buildings.
- Maximum self-consumption can be increased to 50 - 60 % using battery storage.
- In the case of the hotel and the grocery store the ISLANDER solutions PV system size

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is too small in comparison to the consumption, which leads to the fact, that the battery storage is not utilized in the cases 4, 5 and 6.

- In contrast to the household solutions, the self-consumed energy does exceed the energy fed into the grid. In some cases by a lot. This indicates much higher energy demand per square meter for businesses.

6.5 Cost benefit analysis

6.5.1 Approach to the cost benefit analysis

The cost benefit analysis was performed very similar to the household solutions, which is explained in chapter 5.6.1. Additionally, for businesses it must be assumed that tax payments play a role in financial calculations. Therefore, additionally profit after depreciation and tax was considered when calculating economic viability. The tax for businesses and in case of the renewable energy communities was already discussed in chapter 5.4.

6.5.2 From the viewpoint of buildings

Similarly, to the RESS household solutions, in this section it was checked whether the investment in the RESS building solutions and the cases described above are economically viable for individual buildings. Therefore, it only aims to understand the viewpoint of buildings and business owners and whether they might be interested to install the solutions by themselves.

To understand the viewpoint of households, again two cases were studied:

1. Self-consumption using solar PV and battery storage where available, and
2. Feeding all electricity into the grid.

The following table lists the economic results for the first case of self-consumption.

Table 20: Economic viability of the studied cases for the hotel for self-consuming buildings.

Case	Case ID	Financials		PV & Bat. capacity	Self cons.	Total invest	NPV	IRR	Payback period	LCOE
				kW / kWh	%	€	€	%	A	€/kWh
Full optimization	1	ISLANDER		146 / 0	40.7	313,301	56,442	4.1	13.5	0.15
	2	Web research	Min	170 / 0	42.8	124,643	307,271	21.3	4.5	0.05
	3		Max	170 / 0	42.8	234,470	185,969	9.4	8.9	0.10
ISLANDER solution	4	ISLANDER		20 / 81*	9.2	42,918	32,819	9.1	9.0	0.15
	5	Web research	Min		9.2	14,664	65,581	34.2	2.9	0.05
	6		Max		9.2	27,585	50,599	17.0	5.6	0.10
PV optim. and battery cap. = 100 kWh	7	ISLANDER		144 / 100	58.1	401,952	88,200	4.4	11.5	0.19
	8	Web research	Min	170 / 100	62.6	279,876	288,584	11.2	5.5	0.11
	9		Max	170 / 100	62.6	500,585	32,666	2.9	10.6	0.20

*Since the battery was not utilized as described in the conclusion for the cases above, the battery storage system was not included in the financial calculations and the system was treated as it would only contain the PV system.

Table 21: Economic viability of the studied cases for the grocery store for self-consuming buildings.

Case	Case ID	Financials	PV & Bat. capacity	Self cons.	Total invest	NPV	IRR	Payback period	LCOE
			kW /	%	€	€	%	A	€/kWh

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				kWh						
Full optimization	1	ISLANDER		106 / 0	35.9	227,465	67,490	5.2	12.3	0.15
	2	Web research	Min			82,407	233,477	23.7	4.1	0.05
	3		Max			151,686	155,358	11.2	7.9	0.10
ISLANDER solution	4	ISLANDER		20 / 81*	9.9	42,918	32,819	9.1	9.0	0.15
	5	Web research	Min			15,548	64,555	32.2	3.1	0.05
	6		Max			28,620	49,398	16.2	5.9	0.10
PV optim. and battery cap. = 100 kWh	7	ISLANDER		106 / 100	51.5	308,058	88,798	5.1	11.0	0.20
	8	Web research	Min			203,555	209,972	11.2	5.9	0.13
	9		Max			359,370	29,300	3.1	11.2	0.23

*Since the battery was not utilized as described in the conclusion for the cases above, the battery storage system was not included in the financial calculations and the system was treated as it would only contain the PV system.

Table 22: Economic viability of the studied cases for the restaurant for self-consuming buildings.

Case	Case ID	Financials		PV & Bat. capacity	Self cons.	Total invest	NPV	IRR	Payback period	LCOE
				kW / kWh	%	€	€	%	A	€/kWh
Full optimization	1	ISLANDER		20 / 0	33.6	42,918	17,705	6.2	11.3	0.15
	2	Web research	Min			19,120	44,894	20.5	4.7	0.07
	3		Max			32,596	29,674	10.3	8.4	0.11
ISLANDER solution	4	ISLANDER		20 / 81	55.9	80,637	8,735	3.4	14.4	0.28
	5	Web research	Min			75,820	14,320	4.1	13.4	0.26
	6		Max			129,796	-48,267	-2.2	>20	0.45
PV optim. and battery cap. = 20 kWh	7	ISLANDER		20 / 20	46.6	57,934	20,626	5.7	10.6	0.20
	8	Web research	Min			41,692	28,241	10.6	6.5	0.14
	9		Max			71,291	5,138	3.0	11.8	0.25

The following tables show the results of the economic calculations for the second case where all electricity is fed to the grid in order to receive a higher feed-in tariff. Hence, all the following cases are without batteries and without self-consumption.

Table 23: Economic viability of feeding all energy produced to the grid for the hotel.

Case	Case ID	Financials		PV capacity	Self cons.	Total invest	NPV	IRR	Payback period	LCOE
				kW	%	€	€	%	a	€/kWh
Full optimization	1	ISLANDER		146	0	313,301	-143,166	-3.4	>20	0.15
	2	Web research	Min	170		124,643	71,938	10.2	8.4	0.05
	3		Max	170		234,470	-24,793	1.6	17.1	0.10
ISLANDER solution	4	ISLANDER		20	0	42,918	-13,233	-1.3	>20	0.15
	5	Web research	Min			14,664	12,976	13.4	6.8	0.05
	6		Max			27,585	1,596	3.9	13.7	0.10
PV optimized	7	ISLANDER		144	0	307,993	-140,664	-3.4	>20	0.15
	8	Web research	Min	170		124,643	71,938	10.2	8.4	0.05
	9		Max	170		234,470	-24,793	1.6	17.1	0.10

Table 24: Economic viability of feeding all energy produced to the grid for the grocery store.

Case	Case ID	Financials		PV capacity	Self cons.	Total invest	NPV	IRR	Payback period	LCOE
				kW	%	€	€	%	a	€/kWh

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Full optimization	1	ISLANDER		106	0	227,465	-103,886	-3.4	29.4	0.15
	2	Web research	Min			82,407	40,726	9.3	9.0	0.05
	3		Max			151,686	-20,292	1.1	17.8	0.10
ISLANDER solution	4	ISLANDER		20	0	42,918	-13,233	-1.3	23.1	0.15
	5	Web research	Min			15,548	12,197	12.4	7.3	0.05
	6		Max			28,620	685	3.4	14.3	0.10
PV optimized	7	ISLANDER		106	0	227,465	-103,886	-3.4	29.4	0.15
	8	Web research	Min			82,407	40,726	9.3	9.0	0.05
	9		Max			151,686	-20,292	1.1	17.8	0.10

Table 25: Economic viability of feeding all energy produced to the grid for the restaurant.

Case	Case ID	Financials		PV capacity	Self cons.	Total invest	NPV	IRR	Payback period	LCOE
				kW	%	€	€	%	a	€/kWh
Full optimization	1	ISLANDER		20	0	42,918	-13,233	-1.3	23.1	0.15
	2	Web research	Min			19,120	9,051	9.0	9.1	0.07
	3		Max			32,596	-2,817	1.8	16.6	0.11
ISLANDER solution	4	ISLANDER		20	0	42,918	-13,233	-1.3	23.1	0.15
	5	Web research	Min			19,120	9,051	9.0	9.1	0.07
	6		Max			32,596	-2,817	1.8	16.6	0.11
PV optimized	7	ISLANDER		20	0	42,918	-13,233	-1.3	23.1	0.15
	8	Web research	Min			19,120	9,051	9.0	9.1	0.07
	9		Max			32,596	-2,817	1.8	16.6	0.11

6.5.3 From the viewpoint of a renewable energy community

In this section the viewpoint of renewable energy communities is taken by studying the three different business models as already described in more in detail in chapter 5.6.3. The three models are:

1. Rent roof from households and feed-in of all energy produced using only solar PV systems.
2. Landlord tenant model
    a. Energy sales from Landlord (REC) to tenant (household) using only solar PV systems.
    b. Energy sales from Landlord (REC) to tenant (household) using only solar PV systems and battery storage.

Rent roof from households and feed-in of all energy produced using only solar PV systems

In this business model the renewable energy community pays a rent for the roof to the building. The building receives a yearly rent and the renewable energy community installs and operates the solar PV system.

Table 26: Economic viability of renting building roofs of a hotel and selling electricity to the grid from the viewpoint of renewable energy communities.

Case	Case ID	Financials		PV capacity	Building savings		Total invest	NPV	IRR	Payback period
				kW	€/a	% of	€	€	%	a

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						energy bill				
Full optimization	1	ISLANDER		146	4,818	8.6	313,301	-220,028	-8.0	>20
	2	Web research	Min	170	5,610	10.0	124,643	8,506	4.1	13.5
	3		Max	170	5,610	10.0	234,470	-104,983	-3.3	>20
ISLANDER solution	4	ISLANDER		20	660	1.2	42,918	-23,762	-5.0	>20
	5	Web research	Min				14,664	5,514	7.9	9.9
	6		Max				27,585	-5,983	-0.2	>20
PV optimized	7	ISLANDER		144	4,736	8.4	307,993	-216,225	-8.0	>20
	8	Web research	Min	170	5,610	10.0	124,643	8,506	4.1	13.5
	9		Max	170	5,610	10.0	234,470	-104,983	-3.3	>20

Table 27: Economic viability of renting building roofs of a grocery store and selling electricity to the grid from the viewpoint of renewable energy communities.

Case	Case ID	Financials		PV capacity	Building savings		Total invest	NPV	IRR	Payback period
				kW	€/a	% of energy bill	€	€	%	a
Full optimization	1	ISLANDER		106	3,498	6.7	227,465	-159,691	-8.0	>20
	2	Web research	Min		3,498	6.7	82,407	1,175	3.3	14.5
	3		Max		3,498	6.7	151,686	-71,822	-3.7	>20
ISLANDER solution	4	ISLANDER		20	660	1.3	42,918	-23,762	-5.0	>20
	5	Web research	Min				15,548	4,735	7.1	10.5
	6		Max				28,620	-7,184	-0.6	>20
PV optimized	7	ISLANDER		106	3,498	6.7	227,465	-159,691	-8.0	>20
	8	Web research	Min		3,498	6.7	82,407	1,175	3.3	14.5
	9		Max		3,498	6.7	151,686	-71,822	-3.7	>20

Table 28: Economic viability of renting building roofs of a restaurant and selling electricity to the grid from the viewpoint of renewable energy communities.

Case	Case ID	Financials		PV capacity	Building savings		Total invest	NPV	IRR	Payback period
				kW	€/a	% of energy bill	€	€	%	a
Full optimization	1	ISLANDER		20	660	5.8	42,918	-23,762	-5.0	>20
	2	Web research	Min				19,120	1,589	4.3	13.3
	3		Max				32,596	-11,794	-2.0	>20
ISLANDER solution	4	ISLANDER		20	660	5.8	42,918	-23,762	-5.0	>20
	5	Web research	Min				19,120	1,589	4.3	13.3
	6		Max				32,596	-11,794	-2.0	>20
PV optimized	7	ISLANDER		20	660	5.8	42,918	-23,762	-5.0	>20
	8	Web research	Min				19,120	1,589	4.3	13.3
	9		Max				32,596	-11,794	-2.0	>20

Landlord tenant model

In this business model, the renewable energy community installs solar PV and battery storage systems in the buildings. It then sells the produced and stored energy to the household for a cheaper price in comparison to the utility company.

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Energy sales from Landlord (REC) to tenant (building) using only solar PV systems

In this case it was assumed that only solar PV is installed. A battery storage is not included here. Due to economic feasibility, the electricity price that results for the buildings can be as low as 0.16 €/kWh. Accordingly, the buildings can save up to 32 % on their electricity bill. The following table shows the results of the economic calculations. Self-consumption, which is not listed in the tables below, is the same as listed in the tables 23, 24 and 25.

Table 29: Economic viability of the landlord to tenant model for the hotel if only solar PV panels are installed.

Case	Case ID	Financials		PV capacity	Building savings		Total invest	NPV	IRR	Payback period
				kW	€/a	% of energy bill	€	€	%	a
Full optimization	1	ISLANDER		146	6,382	11.4	313,301	-33,077	1.1	17.1
	2	Web research	Min	170	18,110	32.3	124,643	28,432	4.5	11.4
	3		Max	170	12,904	23.0	234,470	-9,441	1.8	15.5
ISLANDER solution	4	ISLANDER		20	1,450	2.6	42,918	10,252	4.6	11.2
	5	Web research	Min		3,903	7.0	14,664	7,396	7.0	8.9
	6		Max		2,781	5.0	27,585	8,702	5.3	10.4
PV optimized	7	ISLANDER		144	7,780	13.9	307,993	13,699	2.7	13.9
	8	Web research	Min	170	22,427	40.0	124,643	47,833	5.9	9.8
	9		Max	170	15,980	28.5	234,470	23,990	3.3	13.0

Table 30: Economic viability of the landlord to tenant model for the grocery store if only solar PV panels are installed.

Case	Case ID	Financials		PV capacity	Building savings		Total invest	NPV	IRR	Payback period
				kW	€/a	% of energy bill	€	€	%	a
Full optimization	1	ISLANDER		106	5,246	10.0	227,465	-10,482	1.8	15.7
	2	Web research	Min		13,846	26.5	82,407	20,043	4.7	11.2
	3		Max		9,739	18.6	151,686	5,464	2.6	14.1
ISLANDER solution	4	ISLANDER		20	1,450	2.8	42,918	10,252	4.6	11.2
	5	Web research	Min		3,827	7.3	15,548	7,486	6.8	9.1
	6		Max		2,691	5.2	28,620	8,807	5.3	10.5
PV optimized	7	ISLANDER		106	6,431	12.3	227,465	26,542	3.4	12.8
	8	Web research	Min		16,973	32.5	82,407	35,106	6.3	9.5
	9		Max		11,939	22.9	151,686	31,016	4.3	11.6

Table 31: Economic viability of the landlord to tenant model for the restaurant if only solar PV panels are installed.

Case	Case ID	Financials		PV capacity	Building savings		Total invest	NPV	IRR	Payback period
				kW	€/a	% of energy bill	€	€	%	a
Full optimization	1	ISLANDER		20	1,079	9.4	42,918	2,222	2.8	13.8
	2	Web research	Min		2,616	22.8	19,120	5,798	5.2	10.6
	3		Max		1,746	15.2	32,596	3,773	3.4	12.8
ISLANDER	4	ISLANDER		20	1,449	12.6	42,918	14,264	5.5	10.3

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solution	5	Web research	Min		3,513	30.6	19,120	11,880	8.0	8.1
	6		Max		2,344	20.4	32,596	13,230	6.1	9.6
PV optimized	7	ISLANDER		20	1,295	11.3	42,918	9,254	4.4	11.5
	8	Web research	Min		3,142	27.4	19,120	9,339	6.9	9.0
	9		Max		2,096	18.3	32,596	9,291	5.0	10.7

Energy sales from Landlord (REC) to tenant (household) using solar PV systems and battery storage

In this case also battery storage was assumed. Some scenarios were left out since they do not include batteries. Due to low economic viability found in this case, the price for the tenant was set as the maximum of 90 % of the energy price from the grid. Hence, the resulting electricity price for the buildings was assumed to be 0.218 €/kWh.

Table 32: Economic viability of the landlord to tenant model for the hotel using solar PV and battery storage.

Case	Case ID	Financials		PV & Bat. capacity	Building savings		Total invest	NPV	IRR	Payback period
				kW / kWh	€/a	% of energy bill	€	€	%	a
Full optimization	1	ISLANDER		Does not include battery solution.						
	2	Web research	Min							
	3		Max							
ISLANDER solution	4	ISLANDER								
	5	Web research	Min							
	6		Max							
PV optim. and battery cap. = 100 kWh	7	ISLANDER		144 / 100	1,969	3.5	401,952	74,355	4.1	13.0
	8	Web research	Min	170 / 100	15,712	28.0	279,876	76,018	4.9	12.6
	9		Max	170 / 100	426	0.8	500,585	63,971	3.6	14.1

Table 33: Economic viability of the landlord to tenant model for the grocery store using solar PV and battery storage.

Case	Case ID	Financials		PV & Bat. capacity	Building savings		Total invest	NPV	IRR	Payback period
				kW / kWh	€/a	% of energy bill	€	€	%	a
Full optimization	1	ISLANDER		Does not include battery solution.						
	2	Web research	Min							
	3		Max							
ISLANDER solution	4	ISLANDER								
	5	Web research	Min							
	6		Max							
PV optim. and battery cap. = 100 kWh	7	ISLANDER		106 / 100	673	1.3	308,058	85,962	5.0	11.8
	8	Web research	Min		9,577	18.3	203,555	86,412	6.3	11.2
	9		Max		-3,698	-7.1	359,370	117,519	5.4	12.0

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Table 34: Economic viability of the landlord to tenant model for the restaurant using solar PV and battery storage.

Case	Case ID	Financials		PV & Bat. capacity	Building savings		Total invest	NPV	IRR	Payback period
				kW / kWh	€/a	% of energy bill	€	€	%	a
Full optimization	1	ISLANDER		Does not include battery solution.						
	2	Web research	Min							
	3		Max							
ISLANDER solution	4	ISLANDER		20 / 81	-2,259	-19.7	80,637	47,449	7.7	9.5
	5	Web research	Min		-1,742	-15.2	75,820	52,433	8.6	9.4
	6		Max		-7,543	-65.8	129,796	82,391	8.1	9.8
PV optim. and battery cap. = 20 kWh	7	ISLANDER		20 / 20	151	1.3	57,934	20,842	5.7	10.9
	8	Web research	Min		1,608	14.0	41,692	21,304	7.0	10.4
	9		Max		-1,047	-9.1	71,291	30,469	6.3	11.2

6.6 Conclusion and recommendation for building solutions

The results of the 5 business models discussed are summarized in the following tables. Only IRR and self-consumption is listed in this table to indicate economic viability and relevance to Borkum's 2030 goal.

Table 35: Results of IRR and self-consumption (IRR/Self consumption in %) summary for the 5 business models studied (LT = Landlord to tenant) for the hotel.

Case	Case ID	Financials		PV & Bat. capacity	Building		Renewable Energy Community		
				kW / kWh	Self cons.	100% feed-in	100% feed-in	LT only PV	LT PV and bat.
Full optimization	1	ISLANDER		146 / 0	4.1 / 40.7	-3.4 / 0.0	-8.0 / 0.0	1.1 / 40.7	-
	2	Web research	Min	170 / 0	21.3 / 42.8	10.2 / 0.0	4.1 / 0.0	4.5 / 42.8	-
	3		Max	170 / 0	9.4 / 42.8	1.6 / 0.0	-3.3 / 0.0	1.8 / 42.8	-
ISLANDER solution	4	ISLANDER		20 / 81*	9.1 / 9.2	-1.3 / 0.0	-5.0 / 0.0	4.6 / 9.2	-
	5	Web research	Min		34.2 / 9.2	13.4 / 0.0	7.9 / 0.0	7.0 / 9.2	-
	6		Max		17.0 / 9.2	3.9 / 0.0	-0.2 / 0.0	5.3 / 9.2	-
PV optim. and battery cap. = 1 kWh	7	ISLANDER		144 / 100	4.4 / 58.1	-3.4 / 0.0	-8.0 / 0.0	2.7 / 49.5	4.1 / 58.1
	8	Web research	Min	170 / 100	11.2 / 62.6	10.2 / 0.0	4.1 / 0.0	5.9 / 53.0	4.9 / 62.6
	9		Max	170 / 100	2.9 / 62.6	1.6 / 0.0	-3.3 / 0.0	3.3 / 53.0	3.6 / 62.6

*Since the battery was not utilized as described in the conclusion for the cases above, the battery storage system was not included in the financial calculations and the system was treated as it would only contain the PV system.

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Table 36: Results of IRR and self-consumption (IRR/Self consumption in %) summary for the 5 business models studied (LT = Landlord to tenant) for the grocery store.

Case	Case ID	Financials		PV & Bat. capacity	Building		Renewable Energy Community		
				kW / kWh	Self cons.	100% feed-in	100% feed-in	LT only PV	LT PV and bat.
Full optimization	1	ISLANDER		106 / 0	5.2 / 35.9	-3.4 / 0.0	-8.0 / 0.0	1.8 / 35.9	-
	2	Web research	Min		23.7 / 35.9	9.3 / 0.0	3.3 / 0.0	4.7 / 35.9	-
	3		Max		11.2 / 35.9	1.1 / 0.0	-3.7 / 0.0	2.6 / 35.9	-
ISLANDER solution	4	ISLANDER		20 / 81*	9.1 / 9.9	-1.3 / 0.0	-5.0 / 0.0	4.6 / 9.9	-
	5	Web research	Min		32.2 / 9.9	12.4 / 0.0	7.1 / 0.0	6.8 / 9.9	-
	6		Max		16.2 / 9.9	3.4 / 0.0	-0.6 / 0.0	5.3 / 9.9	-
PV optim. and battery cap. = 1 kWh	7	ISLANDER		106 / 100	5.1 / 51.5	-3.4 / 0.0	-8.0 / 0.0	3.4 / 44.0	5.0 / 51.5
	8	Web research	Min		11.2 / 51.5	9.3 / 0.0	3.3 / 0.0	6.3 / 44.0	6.3 / 51.5
	9		Max		3.1 / 51.5	1.1 / 0.0	-3.7 / 0.0	4.3 / 44.0	5.4 / 51.5

*Since the battery was not utilized as described in the conclusion for the cases above, the battery storage system was not included in the financial calculations and the system was treated as it would only contain the PV system.

Table 37: Results of IRR and self-consumption (IRR/Self consumption in %) summary for the 5 business models studied (LT = Landlord to tenant) for the restaurant.

Case	Case ID	Financials		PV & Bat. capacity	Building		Renewable Energy Community		
				kW / kWh	Self cons.	100% feed-in	100% feed-in	LT only PV	LT PV and bat.
Full optimization	1	ISLANDER		20 / 0	6,2 / 33,6	-1,3 / 0,0	-5,0 / 0,0	2,8 / 33,6	-
	2	Web research	Min		20,5 / 33,6	9,0 / 0,0	4,3 / 0,0	5,2 / 33,6	-
	3		Max		10,3 / 33,6	1,8 / 0,0	-2,0 / 0,0	3,4 / 33,6	-
ISLANDER solution	4	ISLANDER		20 / 81	3,4 / 55,9	-1,3 / 0,0	-5,0 / 0,0	5,5 / 45,1	7,7 / 55,9
	5	Web research	Min		4.1 / 55,9	9,0 / 0,0	4,3 / 0,0	8,0 / 45,1	9.4 / 55,9
	6		Max		-2,2 / 55,9	1,8 / 0,0	-2,0 / 0,0	6,1 / 45,1	8,1 / 55,9
PV optim. and battery cap. = 1 kWh	7	ISLANDER		20 / 20	5,7 / 46,6	-1,3 / 0,0	-5,0 / 0,0	4,4 / 40,3	5,7 / 46,6
	8	Web research	Min		10.6 / 46,6	9,0 / 0,0	4,3 / 0,0	6,9 / 40,3	7.0 / 46,6
	9		Max		3,0 / 46,6	1,8 / 0,0	-2,0 / 0,0	5,0 / 40,3	6,3 / 46,6

In general, businesses can benefit much more from PV and battery storage solutions than households. Most of the cases and business models studied show positive economic viability. This is most likely since businesses use more energy during times of the day were solar PV systems produce most energy and also have much higher energy demand per square meter of building. Again, smaller PV systems, which increase self-consumption and minimize energy fed to the grid show the best economic values. The business models that target the feed-in of electricity have limited economic viability and can only work if investment costs are leaning towards 1,000 €/kWp for solar PV systems. All landlord to tenant models studied are economically viable, which is great for renewable energy communities. The model with battery storage has even better economics and self-consumption.

Again, it must be noted that those are also attractive solutions for buildings to pursue by themselves with generally slightly better economics. However, the difference is not as big as for the RESS household solutions in this regard. On the other hand, investment costs are high and this could be a niche for the renewable energy community that could focus on bringing actors together to realize the investments for risk averse businesses.

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7 SEWATER DISTRICT HEATING NETWORK AND HEAT SOURCE

In this section the seawater district heating as solution for supplying emission free heat to Borkum is discussed. For this technology an in-depth technological study and cost benefit analysis was not performed. Its complexity of implementation and high estimated investment costs don't make sense as a project to kick-off a renewable energy community. Still, the provision of renewable heat is of great importance for Borkum to achieve its climate goals.

7.1 Background and potential impact

Borkum has set itself the goal of being emission-free in 2030. A particular challenge is the realization of an emission-free supply of heat, which at around 2/3 represents a significant share of the energy demand. Heat pumps can be considered as sustainable and emission-free heat generation technologies that are available all year round. The average heat consumption for the years 2013 - 2018 was 129.8 GWh/a. Almost the entire heat demand of the island of Borkum is covered by natural gas. Some areas are already supplied via heating networks, but these also use natural gas as an energy source, partly in combined heat and power. A local heating network and a supply via a heat pump would therefore have a major impact on the island's CO_2 emissions.

To produce emission free heat a much greater effort is required than just considering the electricity side, as the proportion of heat energy to electricity energy on the island is 4:1. For this reason the seawater surrounding the island has been identified as a potential renewable energy source. A first test was carried out in 2018 as part of a project funded by the DBU (Deutsche Bundesstiftung Umwelt). This test showed the potential of the concept "Heating with the North Sea". Within the ISLANDER project, a new building of about 100 residential units will be supplied with heat from the North Sea.

The overall system of a local heating network consists of a heat generator (heating centre), heat distribution network and house stations. One or more heat generators transfer the heat energy to the transport medium via a heat exchanger. Water is usually used as the heat storage and transport medium. The heated water reaches the heat consumer via underground or above-ground pipes; flexible composite pipes made of plastic or steel pipes are usually used for this purpose. To keep heat losses as low as possible, these should have very good insulating properties. Any type of building can be connected as a consumer point. At the consumer, the heat energy is delivered via a house transfer station and then enters the consumer's heating circuit. The thermal energy can now be used there for heating or for hot water. The cooled water from the heating circuit flows into the return flow of the local heating network and is returned to the heat generator; this creates a circuit between heat generator, heat network and heat consumer. With the use of a heat exchanger, it is also possible to use the heat to provide cooling in commercial and industrial buildings, for example, via such a network.

7.2 Suitability for a renewable energy community (SEZ)

The active involvement of local actors is an important point in the construction of a heating network. Since the economic efficiency of a local heating network increases with the number of connected buildings per area, the aim is to achieve a connection rate of as much as 100 % as possible. Through a cooperation with a renewable energy community, local residents can be involved in the planning and generate benefits for themselves without major hurdles, which increases the support for the planned measures. In this way, municipalities can involve

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their citizens in joint energy transition and climate protection activities. Due to their complexity and the comparatively long period of time from the idea to implementation - a period of one to three years - local heating projects are many times more complex than, for example, the construction and operation of a PV system. There have been successful projects were municipalities collaborated with renewable energy communities to implement a heating network in Germany[11, 12].

7.3 Recommendation

As already stated in the beginning of this chapter, a heating network for Borkum is too complex and investment heavy to kickstart a renewable energy community on Borkum. Still, it is important that the renewable energy community is aware of this topic and is collaborating with the utility company NBG as close as possible to solve the hurdles that may come along with it. It is very likely that a heating network will be part of the solution to achieve the climate goals of Borkum. To realize this, huge efforts must be invested in changing the infrastructure on Borkum. This affects every business and every citizen on the island and therefore can only be achieved if all interests are aligned.

8 SEASONAL HYDROGEN STORAGE SOLUTION

8.1 Background and potential impact

Seasonal hydrogen storage offers long-term storage of renewable energy in form of hydrogen. During peak demand times and when no renewable energy is available it can provide electricity and heat to the island. The main purpose is to store renewable energy during summertime and release the energy during winter times, when generally less renewable energy is available, and more heat is needed. Therefore, it can serve several important purposes for the overall energy system on Borkum.

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[11] https://www.unendlich-viel-energie.de/themen/waerme/energie-kommune_amoeneburg

[12] https://www.energiegenossenschaften-gruenden.de/fileadmin/user_upload/Newsletter-Anhaenge/2013_3_Newsletter_September_2013/Nahwaerme_Schoenstadt.pdf

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8.2 Process

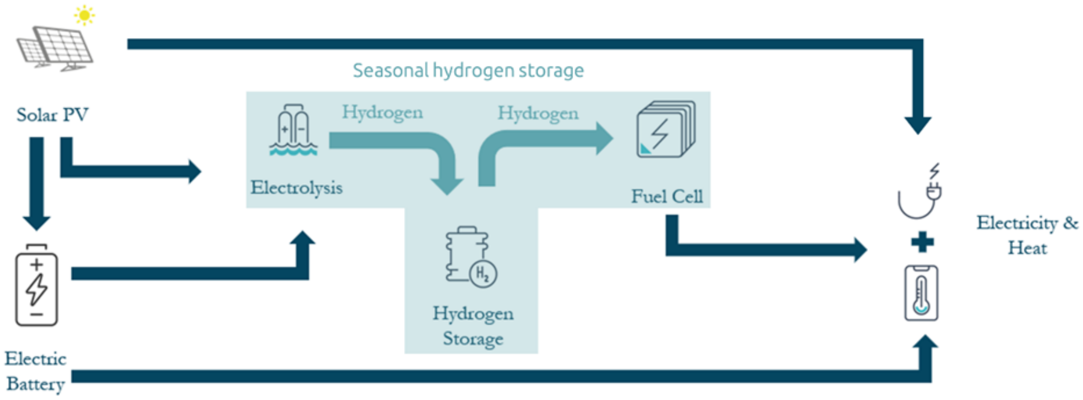

Figure 12. Overview of a general hydrogen-based storage system

The seasonal hydrogen-based storage system is specifically designed to convert renewable electrical energy sources, such as solar and wind, into green hydrogen, which can be utilised later as electricity and heat without generating carbon emissions. This energy storage buffer is suitable for stationary applications, such as integration into buildings or as standalone containerised solutions.

The system accepts electricity and water as inputs and delivers electricity, heat, and water as outputs. It seeks to optimise electricity usage from renewable energies or storage systems (e.g., batteries) rather than the grid for a more efficient operation.

The seasonal hydrogen-based storage solution is equipped with a reversible system capable of both producing and consuming hydrogen. The production of this gas occurs through the electrolysis process, during which water is split into hydrogen and oxygen with the aid of electricity. The hydrogen is then stored in a gaseous state under pressure in specialised tanks. The consumption of hydrogen is facilitated by a fuel cell, which reverses the process and generates electricity and heat.

The solution is ingeniously designed to optimise energy usage autonomously or to be integrated into an energy system controlled by a separate Energy Management System logic. By doing so, the seasonal hydrogen-based storage system ensures that both energy purchase and grid injection are minimised.

8.3 Main components, cost and installation

The list of main components, their cost and their properties were taken from a commercial offer from the ISLANDER project. The following table lists the main information available.

Table 38: Main components of the ISLANDER seasonal hydrogen storage solution and their properties.

	Electrolysis	Compressor	H_2 storage	Fuel cell
Capacity	25 kW	6 Nm³/h H_2	150 kg @ 300 bar	16 kW
Cost installed*	7,000 €/kW	10,000 €/Nm³/h H_2	1,000 €/kg H_2	7,000 €/kW
Lifetime	35,000 h	20,000 h	1,000 cycles	10,000 h
Efficiency	70 %	80 %	-	53 % (85 %**)

*: All costs are estimations based on the information available from a commercial offer within the project. The offer is for a packaging unit including housing in the form of a containerized unit. Thus, costs include all equipment needed for the equipment to be operated except connection at the interfaces with the surroundings, e.g. electricity grid and water supply.

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**: According to literature a fuel cell could achieve ca. 85 % efficiency if the heat produced during electricity production can be reused.

Since the hydrogen storage solution is delivered as a packaging unit from the commercial supplier, all installation tasks are related to connecting the system with the interfaces needed for operation, e.g. electricity grid and water supply.

8.4 Cost benefit analysis

To check preliminary economic viability of the seasonal hydrogen storage solution a simpler approach was chosen in comparison to the solar PV and battery storage solutions. It was quite clear from the beginning that the system is likely not going to be economically viable, hence the goal was to estimate the status and give an outlook on where economics roughly need to go in the future. The simplifications are:

- Electricity price which is used as input and thus cost for the calculation was set to 0.1 €/kWh, which is a good approximation of prices for renewable energy. It neglects the fluctuating prices at the energy market, which can be lower or higher at times. Ideally, the operator of a seasonal hydrogen storage would aim to buy electricity at times when it is cheapest.
- Electricity sales price was assumed to be around the current price on Borkum of 0.39 €/kWh. Price of heat was set to 0.15 €/kWh like current prices for heat from heating networks on Borkum.
- The seasonal hydrogen storage can act as a stabilizing element in the management of electricity grids. Thus, the value of its electricity is much higher than renewable energy from wind or solar as it can be produced on demand. This can potentially result in quite complex business models that may be more of interest for utility companies that require to stabilize their grid or must pay fees to transmission network operators if their grid stability is not kept within contractually defined boundaries. These business models have not been included here due to their complexity, especially from a viepoint of a renewable energy community.
- As can be seen from Table 38, the lifetime of the different components isn’t aligned. For this analysis it was assumed that the lifetime of the plant is 20 years. The costs of the components have then been adjusted to achieve this lifetime. Depending on the case an adjusted CAPEX was calculated which can be the best case from an economic point of view as it maximizes operating hours for the equipment and thus minimizes the effect of investment costs on the results of the calculation. This estimation basically is equal to the maximum of 8,760 full load hours per year.
- Maintenance cost for chemical plants can be assumed to be roughly 5 % of CAPEX per year. This is especially true for complex processes that use catalyzing materials as it’s the case in electrolysis and fuel cells. For this calculation it was assumed that maintenance cost is 2 %, which is closer to what is currently the case for renewable energy production. This again can be considered a best-case scenario.

The first case studied in the cost benefit analysis was built on the assumption that the hydrogen storage is filled once during summer to provide electricity during winter times. Heat recovery and sales are neglected in this case. In this case the ISLANDER system is operated for 286 h during summer to fill its storage. This leads to an adjusted total cost of the system of ca. 112,000 € considering its high lifetime at this low utilization. Accordingly, maintenance costs are 2,254 € annually. Electricity costs are 839 € annually and revenue from electricity sales is 1,014 € annually due to an overall efficiency ca. 30 % for the overall system. As a result of this the annual loss before accounting for depreciation of the investment is 2,080 €. This also results in a negative NPV of ca. -145,000 € of the investment over a period of 20 years. Finally,

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using these assumptions the LCOE can be estimated to be 3.9 €/kWh, ten times the price of current electricity on Borkum. Including the sale of recovered heat can increase overall efficiency to 48 %. Accordingly, the LCOE is reduced to ca. 2.4 €/kWh.

Looking at the different cost positions, it is evident that depreciation of investment costs are the major cost driver with 64 % of annual costs. Maintenance, being dependent on the CAPEX, accounts for 26 % of annual costs. And finally, electricity only accounts for 10 % of annual costs. For the ISLANDER system the specific costs are ca. 27,000 €/kW of installed electrolysis capacity. To be economically viable in the case presented here investment cost must be reduced by ca. 95 %. This would lead to specific investment costs of ca. 1,350 €/kW, which is comparable to current solar PV systems.

There are several pathways available to reduce costs of the seasonal hydrogen energy storage as installed in the ISLANDER project. One common approach is economy of scale which indicates cost reduction by installing larger sized plants. Assuming common scaling exponents for economy of scale, systems with ca. 10 MW or larger could potentially be economically viable. However, at this size a single plant would already require a total investment volume above 10 M€. Another possibility to reduce cost would be to look at the learning rate of the technology which describes the cost reduction through improvements by installing more total capacity of the technology in the market over time. At a learning rate of 20 % as it was the case for solar PV (20 % cost reduction for each doubling of total capacity installed) this can take many years. E.g. solar PV lost its initial 90 % of costs from 1976 to 1986. It then took roughly 30 years more for solar PV panels to reduce another 90 % of its cost.

8.5 Recommendation

Seasonal hydrogen storage currently still faces many challenges for commercial application. The technology is still in development, which also includes the heat recovery of such systems. That is accompanied by high investments costs due to early product development stage. Even if it might be economically viable to scale the technology and thus reduce costs, it is certainly risky to do so considering the early development stage and open technological questions such as hear recovery and long-term stability. Still, those larger scale systems also introduce the hurdle of high upfront cost of 10 M€ or more, which is especially not suitable for a renewable energy community in the early stage. Assuming a learning curve of 20 % it may take 10 years or more to reduce costs for smaller systems. Thus, it currently cannot be expected that small scale hydrogen storage systems can play a major role in Borkums 2030 goal. Additionally, it is questionable what the electricity will be cheap in the future, as the case also highly depends on cheap electricity. With increasing electrification of transport, heating, and industry electricity this must be second guessed. Finally, heat integration of the hydrogen storage system also faces challenges like other heating network technologies including costs for currently unavailable infrastructure.

To conclude, a seasonal hydrogen storage system is currently no feasible option for a renewable energy community. Still, its development should be observed for future applications as it may be a key piece to realize a fully emission free energy provision for Borkum.

9 ALTERNATIVE ENERGY FAIRIES

The ferries to and from the island of Borkum are operated by the shipping company AG "EMS". Ferries sail to Borkum from two locations: Emden (Germany) and Eemshaven (Netherlands).

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The fleet consists of 3 ferries, which can carry about 1200 passengers and about 70 cars, as well as 2 catamarans, which can carry 450 and 270 passengers respectively. Two of the ferries have been restored and converted to LNG ferries in recent years, reducing emissions such as sulphur oxide and nitrogen oxide by up to 80%, carbon dioxide by 20% and particulate matter almost entirely.

Throughout the year there are about 730 round trips from Emden to Borkum, 660 catamaran trips and about 880 round trips from Eemshaven to Borkum[13]. The ferry from Emden to Borkum takes 2.2 hours, while the catamaran only takes 1 h for the trip. From Eemshaven to Borkum the ferry takes 50 minutes. With an estimated consumption of 1000 l/h of fuel, this adds up to a consumption of 5,974,040 litres of fuel per year for all ferry and catamaran rides to the island of Borkum. This consumption leads to an estimated emission of approx. 13,000 tCO$_2$. Compared to the annual CO$_2$ emissions of Borkum (without the ferry business?), which lie around 32,000 tCO$_2$ the ferry operations have a big impact on the CO$_2$ emissions of Borkum and need to be considered when addressing the decarbonisation of Borkum.

Eventhough alternative energy ferries would be an important topic for the decarbonisation of Borkum, this topic is not suitable for a renewable energy community. With progressing decarbonization of Borkum, this topic should be reevaluated in the future.

MS “Münsterland”

The ferry MS "Münsterland" was converted in 2020 to use LNG. It was the third ferry of the fleet being converted to use the environmentally-friendly fuel.

Construction	1986 (Conversion 2022)
Passengers	1,200 people
Cars	max. 75
Speed	15,5 knots
Engine power	2 x 1050 kW
Length	94,00 m
Width	12,60 m
Draught	2,35 m

MS “Nordlicht II”

The hightech catamaran only needs 60 minutes to travel between Borkum and the mainland. This is twice as fast as the other conventional ferries take for the same distance.

Construction	2021
Passengers	450 people
Speed	35 knots
Engine power	2x 2960 kW
Length	46,80 m
Width	11,00 m
Draught	2,40 m

MS “Ostfriesland”

The MS “Ostfriesland” became Germany’s first LNG ship with its conversion in 2015. LNG stands for liquified natural gas and it’s a gas, mainly consisting of methane, cooled to -162

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[13] https://cdn.ag-ems.de/fileadmin/AG_EMS/6_Download-PDF/AGE/2023/AGE_DINlang_FP_2023_aktuell_WEB.pdf?_gl=1*13w8czx*_ga*NDU2Mzc2MzY4LjE2NzM0NDU3NDA.*_ga_YD85LDBNFX*MTY3Mzg2MjQxOS4zLjAuMTY3Mzg2MjQxOS4wLjAuMA

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°C, which makes it liquid and increases energy density. LNG helps to reduce the environmental impact. In comparison to shipping diesel, emissions of sulphur components and nitrogen oxides are reduced by 80 % and carbon dioxide emissions are reduced by 20 %. Particulate matter is avoided almost completely.

Construction	1985 (Conversion 2015)
Passengers	1.200 People
Cars	max. 70
Speed	16 Knots
Engine power	2x 1.564 HP
Length	94,00 m
Width	12,60 m
Draught	2,40 m

MS „Nordlicht“

MS “Nordlicht” is a high speed catamaran for passenger transportation similar to the MS „Nordlicht II”.

Construction	1989
Passengers	272 People
Cars	-
Speed	38 knots
Engine power	2x 2.774 HP
Length	38,80 m
Width	9,44 m
Draught	1,55 m

10 LIST OF RESOURCES AND CONTACTS

Within the previously published deliverable D7.3 a list of resources and contacts was compiled to quickly get an overview of the issues surrounding energy communities. Those helpful guides and websites on various topics are shown below.

Table 39 – List of useful information materials for the foundation of energy communities.

	Content	Weblink
Formation of an energy cooperative	Website of the cooperative federation (Genossenschaftsverband) with information on setting up a registered cooperative. The individual steps from the idea of formation to registration are described and explained in short videos. There are many sample documents and checklists	[Weblink]()
	The brochure published by the EnergyAgency NRW provides an overview of citizen energy in Germany, possible forms of association, financing options and practical examples.	[Weblink]()

	A brochure describing different possible business models for citizens' energy cooperatives and how to develop a business model for an energy cooperative	Weblink
	This guide explains in detail the individual steps needed to set up an energy cooperative.	Weblink
	This brochure deals with the ecosystem of citizen energy. With a stakeholder analysis, important reference groups can be analysed and corresponding strategies and activities can be derived from them. In addition, external actors such as municipalities are examined	Weblink
	Reasons for and advantages of cooperation between municipalities and citizens' energy cooperatives	Weblink
	Summary table comparing different business forms of an energy community	Weblink
Local heating network	Practical guide to setting up a community heating network from the start-up phase to technical components and implementation	Weblink
	Practical guide with implementation possibilities and advantages of local heating networks	Weblink
Usefull contacts	The network **Energiewende Jetzt e.V.** promotes the establishment and further development of energy cooperatives as well as the cooperation and networking of actors in the field of citizen energy in Germany, Europe and worldwide.	Weblink
	The cooperative association **Verband der Regionen e.V.** is an auditing and advisory association, training provider and lobby group for around 2,600 member cooperatives. To support the foundation of cooperatives they offer a lot of information materials on their website.	Weblink
	The **EUCENA project** offers Open Learning courses to educate people on how to harness renewable energy and also offer sources of support and community that are essential for creating long-term sustainable energy systems.	Weblink

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11 MAIN CONCLUSIONS

Borkum's journey towards CO_2 neutrality hinges on a robust renewable energy community. By leveraging solar PV systems, battery storage, and promoting collaboration between businesses, households, and utility companies, we can pave the way for a sustainable and prosperous future. The key lies in maximizing self-consumption, minimizing grid feed-in, and ensuring economic viability while embracing evolving technologies for the island's decarbonization. Creation of a vibrant and thriving renewable energy community can stand as a beacon of progress and sustainability for Borkum. The following table summarizes the results of this study.

Table 40: Summary of the study.

Technology pathway	Result of the study
Solar PV Systems and Battery Storage for Households	The case study reveals that solar PV systems hold substantial economic viability for Borkum's households. An effective strategy would be: • Affordable Solar PV Systems: Encourage households to adopt solar PV systems with prices around 1,167 €/kWp, maximizing self-consumption while minimizing grid feed-in. • Battery Storage for High Self-Consumption: Propose the ISLANDER project's battery storage solution for households aiming at 98% self-consumption. Emphasize high self-consumption and keeping costs low as priorities. • Roof Rental Model: Promote renting rooftops from private homes, installing solar PV systems, and feeding excess energy to the grid. Highlight potential for both financial benefits and reduced energy bills.
Solar PV Systems and Battery Storage for Businesses	Businesses stand to gain significantly from solar PV and battery storage. Key recommendations are: • Maximizing Self-Consumption: Advocate for solar PV systems that maximize self-consumption (33-43%) and add battery storage to further enhance it (50-60%). • Landlord-Tenant Models: Encourage businesses to consider landlord-to-tenant models, with solar PV and battery storage solutions showing positive economics and potential for even better performance. • Collaboration and Alignment: Stress the importance of collaboration with utility companies to overcome hurdles and drive the potential integration of a seawater district heating network.
Seawater District Heating Network and Heat Source	While a heating network presents challenges, collaboration with the utility company is crucial. Ensure alignment of interests across businesses and citizens to facilitate the transition.
Seasonal Hydrogen Storage	Currently, small-scale hydrogen storage isn't feasible due to challenges in technology, costs, and uncertainties. Keep an eye on its development, but focus efforts on proven solutions for now.
Alternative Energy Ferries	Though alternative energy ferries could reduce emissions significantly, it's not an immediate focus for the renewable energy community due to complexities. Monitor advancements

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	for future considerations.

Building upon this study, a series of citizen engagement workshops will guide Borkum's community towards practical renewable energy solutions. These workshops progressively move participants from understanding the CO_2 neutrality goal to embracing clean energy integration. Beginning with an introduction and visioning session supported by the utility company of Borkum and the island’s council, participants grasp the significance of a renewable energy community. Insights from solar PV and battery storage case studies, along with input from external experts, substantiate these concepts. Citizens will be enabled to delve into tailored solutions for specific projects on the island. Households explore the economic feasibility of solar PV and batteries through simulations and expert advice. Businesses uncover the benefits of adopting these technologies, fostering collaboration among participants. The journey concludes with a collective commitment to apply gained knowledge. This will support the transformation of Borkum's vision into an achievable, sustainable reality.

DEVIATIONS

Delivery of the content was delayed in time but to full satisfaction, without any deviations and consequences to actions planned.

ANNEX A: COST COMPARISON

Capacity in kWp	Source	Link	Costs incl. Installation	Costs per kWp
5,5	EON	Link	14,255 €	2,592 €
6,5	EON	Link	16,663 €	2,564 €
7,5	EON	Link	17,247 €	2,300 €
8,5	EON	Link	18,479 €	2,174 €
10	EON	Link	20,767 €	2,077 €
11	EON	Link	22,439 €	2,040 €
13	EON	Link	26,487 €	2,037 €
4	ISLANDER project		12,601 €	3,150 €
20	ISLANDER project			
4	co2online	Link	5,820 €	1,455 €
10	co2online	Link	13,400 €	1,340 €
8	Wegatech	Link	17,000 €	2,125 €
9	Wegatech	Link	18,000 €	2,000 €
10	Wegatech	Link	19,000 €	1,900 €
11	Wegatech	Link	20,500 €	1,864 €
12	Wegatech	Link	22,500 €	1,875 €
3	Solaranlagen-portal	Link	5,400 €	1,800 €
4	Solaranlagen-portal	Link	6,300 €	1,575 €
5	Solaranlagen-portal	Link	7,600 €	1,520 €
6	Solaranlagen-portal	Link	9,000 €	1,500 €

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7	Solaranlagen-portal	Link	10,400 €	1,486 €
8	Solaranlagen-portal	Link	11,000 €	1,375 €
9	Solaranlagen-portal	Link	12,900 €	1,433 €
10	Solaranlagen-portal	Link	13,300 €	1,330 €

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