REMOTE

Project n° 779541

"Remote area Energy supply with Multiple Options for integrated hydrogen-based TEchnologies"

Deliverable D2.1

Analysis of the economic and regulatory framework of the technological demonstrators

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Abstract:

This REMOTE deliverable results from Task 2.1 and describes the analysis of the economic and regulatory framework of the technological demonstrators. From the analysis it can be concluded that the main driver for the business cases at the four demo sites varies from reducing electricity costs and emissions in the current situation to avoiding costly investments and financial risk for maintaining, replacing or strengthening the grid connection.

Legal-administrative barriers may represent an obstacle to a quick deployment of the DEMO installations. These barriers may reflect a lack of acknowledgement of the key features of the installations within national legal codes and local planning by-laws, along with additional bureaucracy and complex sets of procedures and requirements.

The work has been led by SINTEF with contributions from partners ENEL Green Power (EGP), Horizon SA (HOR), IRIS srl (IRIS), Trønder Energi (TREN), and Powidian (POW).

Keyword list:

Hydrogen
Power-to-Power (P2P)
Energy storage
Off-grid
Remote areas
Economic framework
Regulatory framework

Contents

1 Background and introduction

The EU requires a strong commitment from all member states to develop a Resilient Energy Union to provide consumers with secure, sustainable, competitive and affordable energy. To meet post-2020 targets, a higher penetration of “new” renewables like solar and wind is needed. These sources have a higher power density than biomass, but the issue of intermittency has to be solved. A promising option is to develop bulk energy storage solutions for electricity that are cost-effective, energy dense and reliable. Figure 1 shows a conceptual illustration of energy storage under intermittency conditions.

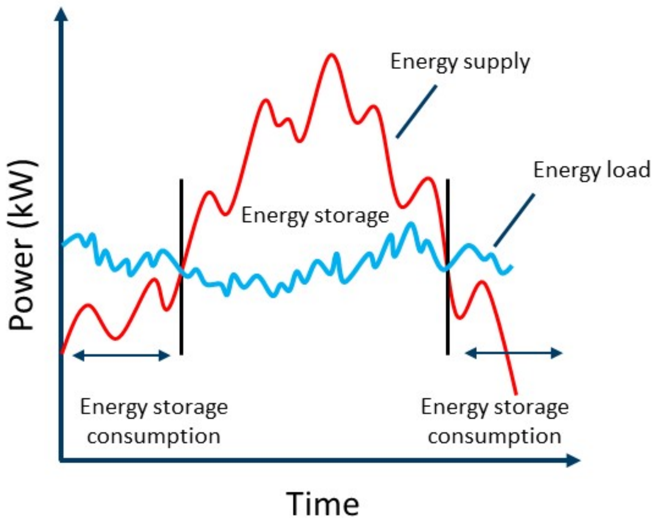

Figure 1. Conceptual illustration of energy storage under intermittency conditions (Source: SINTEF)

For isolated micro-grid or off-grid remote areas, a distribution network is essentially non-existent or there is an interest in managing the local network in an independent way. Here, the business case is different and energy storage can be a game changer to improve self-sufficiency. Intermittent renewable energy sources (PV, wind, wave) provide a cost-efficient and decarbonized alternative to on-site electricity generation through diesel engines. Stationary battery systems are easy to implement to store energy on daily basis. However, often energy storage is needed for more than one day and batteries become expensive. Then, integration with fuel cell- and hydrogen-based power-to-power (P2P) systems with medium- to long-term storage capabilities (from several days to weeks or months) is seen as the most viable and reliable option. An example of such an integration is shown in Figure 2.

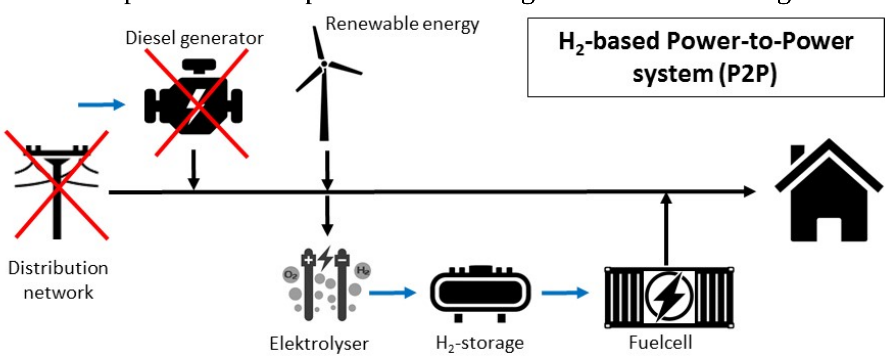

Figure 2. An example of integration with fuel cell- and hydrogen-based power-to-power (P2P) systems (Source: SINTEF)

The REMOTE project shall demonstrate the technical and economic feasibility of fuel cells-based H_2 energy storage solutions in isolated and off-grid remote areas. Four demo solutions, with supply by renewable energy sources (RES), will be installed in either isolated micro-grids or off-grid remote areas: at Ginostra (South Italy), Agkistro (Greece), Ambornetti (North Italy) and Froan Islands (Norway), see Figure 3. These demos comprise two different plant architectures, an integrated P2P system and a non-integrated power-to-gas and gas-to-power (P2G+G2P) system, with different loads to be covered and different types of RES available on-site. The variety of the demo cases can help suppliers, end users and general stakeholders to gain experience. It also demonstrates energy and environmental advantages of fuel cells-based H_2 energy storage solutions to the broader energy community and to decision makers willing to support more sustainable technologies. This paves way for the deployment of such energy storage solutions at large.

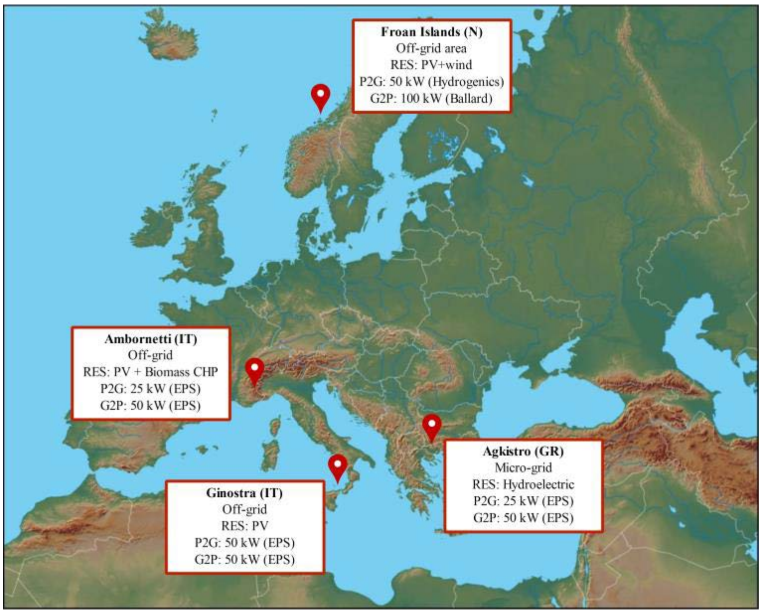

Figure 3. The four demo sites in the REMOTE project

Work package 2 in the project, "Use cases: definition of the technical and business cases of the 4 demos" is concerned with defining the technical, economic and regulatory context and the subsequent business cases for the demonstration plants. This assures correct design and contextualization from a business perspective before their commissioning in work packages 3 and 4.

For each of the demo cases, work package 2 assesses why it shall be developed (Task 2.1), taking into account the economic and regulatory framework, and how the identified targets shall be achieved with the proposed technical solution (Task 2.2). This specifies technical parameters of each demonstrator, taking into account site-specific features, and feeds into the detailed engineering and installation phases in work packages 3 and 4. The evaluation includes a definition of the expected economic outcomes and business cases (Task 2.3) to be analysed during the implementation and working phases of the demo cases, allowing their revision and updates before moving to the exploitation studies performed in work package 6. The work package defines also the control strategies of the complete demo systems and evaluates how the choice of control strategy affects the business case definition. Finally, a common monitoring and acquisition strategy will be defined to assure homogeneity of the gathered data as a basis for a fair and correct analysis and comparison of the achieved results across all four demo cases.

The main objective of Task 2.1 "Analyses of the economic and regulatory framework for the four demonstrators" is to describe the technical, economic and regulatory framework of the technological solutions implemented in the single demo cases, i.e., to detail the motivation for developing the demos.

This framework has a paramount effect on the technical definitions and the potential economic revenues of smart electric systems relying on RES and storage processes. Obviously, the electricity tariff at the site (structuring of the tariff on hourly basis, kWh cost, etc.) is important. Moreover, imbalances between energy production and supply, and integration between district infrastructure and local loads, affect options for storage and peak shaving in key technologies. The regulatory context has a huge influence on the technical design of the adopted technologies and on their economic results and business opportunities. In addition, environmental concerns will play an important role for an adoption of the envisaged renewable solutions. The information assembled in Task 2.1 establishes a starting point for Task 2.2 describing how to improve each local situation by way of detailed technical specifications.

This report presents results from this task and establishes Deliverable D2.1 of the REMOTE project, which describes the "*Analysis of the economic and regulatory framework of the technological demonstrators*". The work has been lead by SINTEF with contributions from partners ENEL Green Power (EGP), Horizon SA (HOR), IRIS srl (IRIS) and Trønder Energi (TREN).

The scope of this deliverable is limited to the four demo sites and is based on information and data collected from the respective partners early on in the project.

Section 2 describes the current situation and the planned technical solutions at each site from a system perspective. Sections 3 and 4 are concerned with the economic and regulatory framework, respectively. Concluding the report, section 5 summarizes why the technical solutions should be developed at the demo sites.

2 System design description

The demo cases comprise different typologies of user loads, i.e., residential and small industrial (SME), with different load profiles, affecting the design of the fuel cells-based energy storage solutions and, in particular, protocols to manage the micro-grids. To feed these loads in the different cases, electricity will be used directly, either from intermittent (e.g., solar PV panels) or more predictable and stable sources (e.g., mini-hydro). This leads to different models of energy management inside the micro-grids and to different models to

- design hydrogen-based energy storage solutions (size of the electrolyzer, size of the H_2 storage);
- identify methodologies to optimize the design of these typologies of systems;
- design protocols to manage the electric flows inside the micro-grids.

Two architectures of storage solutions will be installed and monitored during the project, an integrated P2P system (manufacturer EPS) and a non-integrated P2G+G2P system (manufacturers BPES and HYG, integrator POW), giving access to a variety of data to compare the two architectures. Currently, storage solutions are not in place for any of the demo sites.

2.1 Demo 1. Ginostra (South Italy)

Ginostra is an island village, not connected to the Italian distribution and transmission grid. It is also disconnected from the main Stromboli Island grid and, hence, classified as off-grid. All loads are residential. The demo site is characterized by a complex and expensive accessibility.

Figure 4. Map illustrating the geographical location of Ginostra

The village counts about 40 people living there during the year, while during summertime there are about 200 people due to tourism. The economy of the village is based only on tourism-related activities, such as restaurants, bars, mini-markets and guesthouses. There are some public services, like a medical ward, a small harbour and a heliport. Therefore, the village's energy requirements vary seasonally between 10 MWh/month and 30 MWh/month. Currently, the site load is covered by three 48 kW diesel generators and one 160 kW diesel generator satifying the total village demand. Due to the demo site's geographical location, all fuel must be transported in by helicopter, leading to transportation and logistics issues and, not at least, high costs for electricity generation. The village shall become independent of fossil fuels or, at least, the use of diesel generator shall be minimized, reducing diesel consumption to less than 10%. The demo is also expected to induce a better and more efficient use of renewable sources and an improved electricity service and grid quality. End user of the solution is the utility ENEL Green Power (EGP).

The proposed solution is the Li-Ion-battery based Hybrid Energy Storage System (HyESS™) of EPS, provided in kind by EGP, together with a photovoltaic array, and a P2P hydrogen storage system provided by EPS. The HyESS™ system will reduce the use of diesel generators up to 100% to cover the entire energy demand (depending on specific renewable resource and plant availability). This will result in fuel savings of approx. 65 000 litres per year which corresponds to 120 k€ per year due to the high transportation cost of the diesel fuel. RES will cover about 60% of the load profile, while the remaining energy will be managed by the HyESS™ system. The selected size of hydrogen storage allows performing some seasonal storage: it is kept almost full during the winter and used completely during the summer, because of increased consum due to tourism. During the winter, all energy demand is satisfied by RES with some contribution from the storage. The proprietary Energy Management System (EMS) will manage the power flows (renewables, batteries, electrolyser, fuel cell system etc.) and the related control functions.

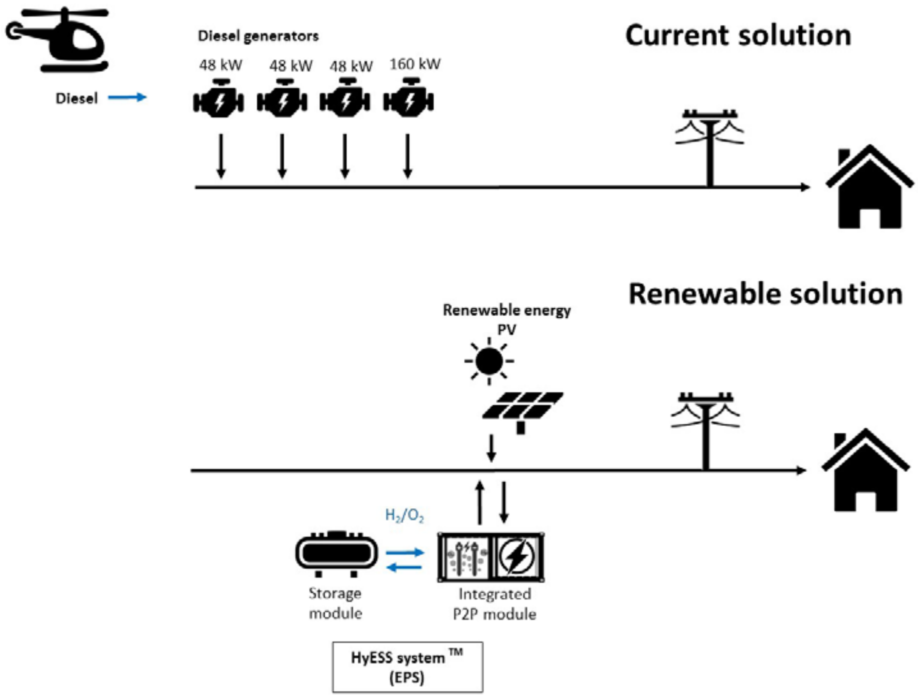

Figure 5. The current and suggested renewable renewable solutions for the Ginostra demo site

2.2 Demo 2. Agkistro (Greece)

Agkistro is a remote village, and the demo site can be considered off-grid. Loads are industrial (SME). The main driver for the proposed solution is the expensive cost for new transmission lines.

At the demo site, there is an existing hydroelectric plant with connection to the grid. It functions all year round with constant, but not always stable, water supply from springs and provides electricity to the main grid (20 kV). The grid is unstable and has frequent outages, up to 10 times per month and up to 3 hours each. The owner of the hydroelectric plant plans to build an agrifood processing unit very close by. To connect this unit to the grid, the company will need to build a separate line directly to another high voltage transformer 20 km away, since the local transformer is full. In this case, it also would have to pay extravagant taxes and buy energy far more expensive than sold from the hydro plant. End user of the solution will be the owner of the hydroelectric plant, Horizon SA (HOR).

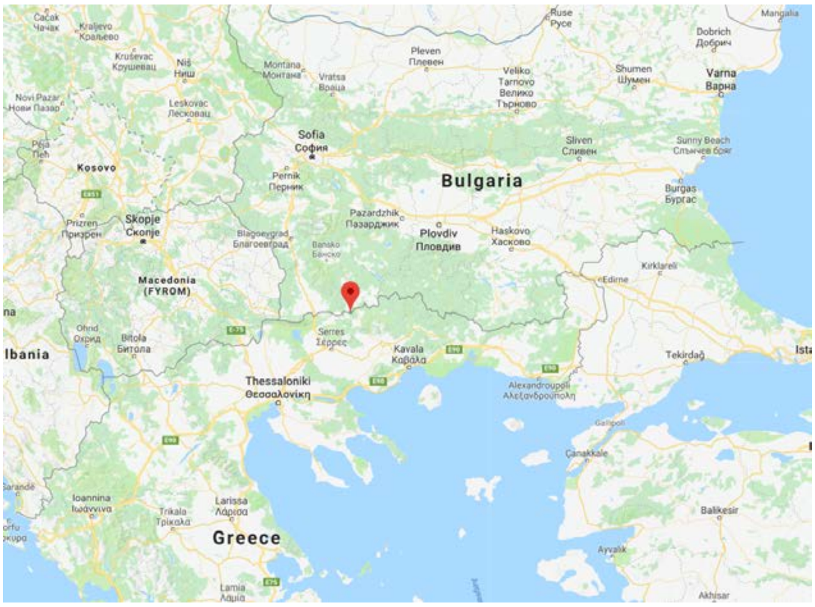

Figure 6. Map illustrating the geographical location of Agkistro

The aim is to make the agrifood processing unit energy autonomous, without connection to the grid but, instead, relying on the hydro plant and a hydrogen-based storage system. This way, excess electricity production from the hydro plant can be used efficiently, in addition to having a renewable back-up system in case of emergency. Moreover, this secures a stable electricity supply, without disruptions of processing procedures and ensuing product deterioration. The hydrogen storage solution together with the power management system would also allow to regulate the frequency and the voltage of the load with some hours of back-up.

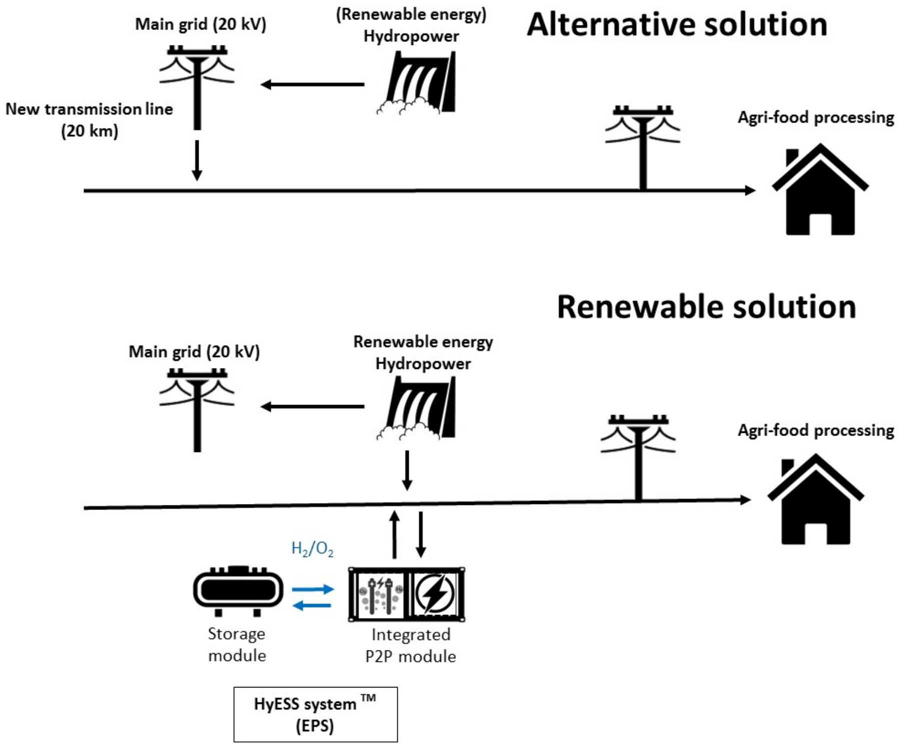

Figure 7. The alternative and renewable solutions for the Agkistro demo site

The configuration of the P2P system to be provided benefits from the continuous availability of a renewable source (hydro plant) that allows to minimize the P2G sizing while covering peak load requests and guaranteeing back-up energy for 2-3 days thanks to the hydrogen storage (500 kWh equivalent net energy). The EMS will govern power flows (hydro, electrolyzer, fuel cell system etc.) and related control functions, optimizing overall plant operation with a specific control strategy based on site requirements.

2.3 Demo 3. Ambornetti (North Italy)

The mountain hamlet Ambornetti (1600 m a. s. l.) is an off-grid site, carrying residential loads. It is characterized by a complex and expensive accessibility and expensive costs for new transmission lines.

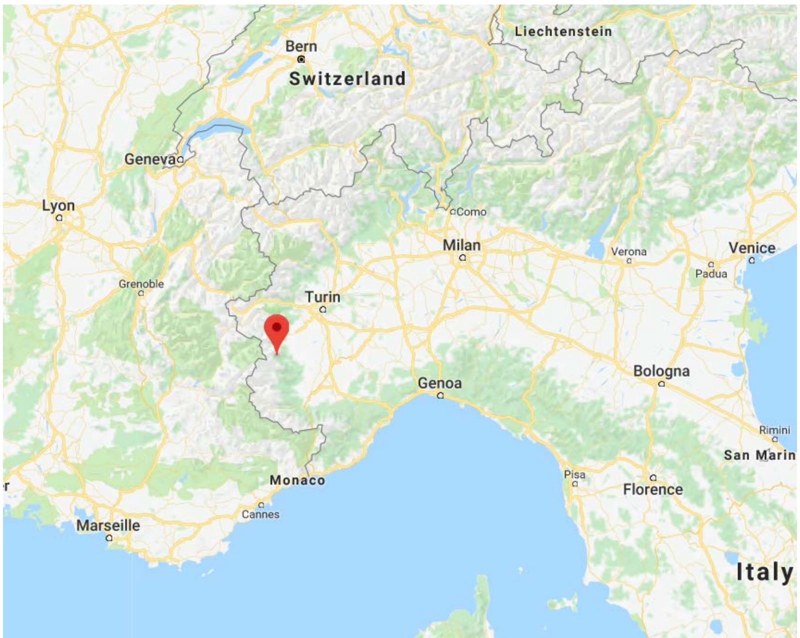

Figure 8. Map illustrating the geographical location of Ambornetti

Ambornetti has never been connected to the grid but is now object of a large renovation project, to bring life, technology and economic activity in that rural area with neutral impact on the environment. A connection to the electric grid (nearest point of access 400 m below) would mean costly and invasive works and/or infrastructure – either unsightly transmission towers or kilometres of trenched cables. At project completion, Ambornetti will become a completely off-grid community powered by solar energy and a combined heat and power generator using local biomass, with no need of fossil fuel backup. The biomass originates from forests requiring management and from local agricultural waste and is available year round. Hydrogen-based technology shall minimize the critical lifecycle impact of the energy storage system. The demo represents a first of its kind example of integrating energy storage with power generation from biomass and from PV. End user will be one of the hamlet's stakeholders, IRIS srl (IRIS).

Power generation for the community shall be provided entirely by renewables: 40 kW from photovoltaic, 50 kW from local biomass, using an innovative concept of modular gasification. On a yearly basis, PV covers more than half of the load profile (55%), while the remaining half is satisfied by biomass (33%) and the P2P system (12%). While in winter almost all PV production directly serves the load and just a small amount of energy is available to be stored, in summer 50% of PV production would directly serve the load, 46% would go to charge the P2P, 2% would go to charge batteries without any curtailment. Thus, a possible load coverage on a typical summer day can be: PV is the main source for covering load in the sunny hours, followed by P2P and batteries in the evening. The biomass generator is used to cover the remaining hours. With biomass available on site all year long, the CHP generator can be considered a constant power generator, and the hydrogen storage has been preliminarily sized to provide one day of energetic autonomy (i.e., 260 kWh equivalent net energy). The EMS governs the power flows (renewables, batteries, electrolyser, fuel cell system etc.) and the related control functions, such that the operation of the overall plant will be optimized based on the site's requirements. Because of the dual use of the CHP generator, energy management will also need to balance overall energy needs, making the P2P system an integral part of a complex system: to harmonize energy generation with load requirements, to manage the intermittency of photovoltaic production and to integrate unit power provided by the biomass generator in the energy management.

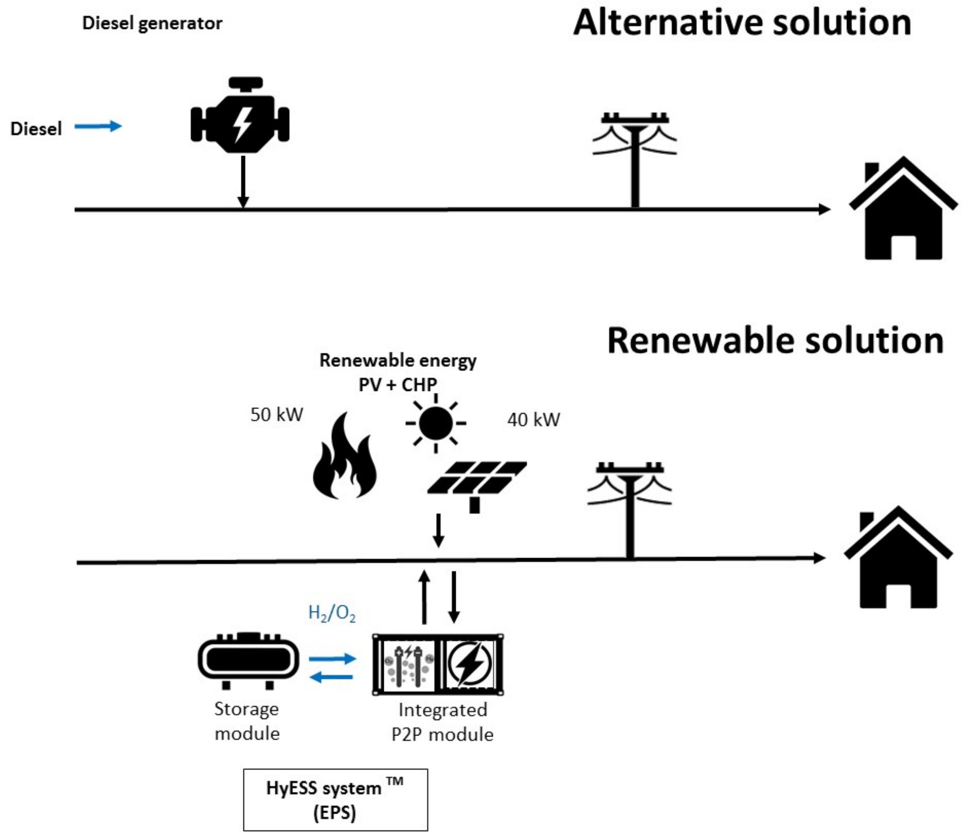

Figure 9. The alternative and renewable solutions for the Ambornetti demo site

2.4 Demo 4. Froan / Rye (Norway)

The islands community Froan represents a micro-grid today, but will be off-grid or an isolated micro-grid in about 5 years time. Loads are both residential and industrial, and the driver for installing the proposed solution is expensive costs for updating an existing transmission line.

There are 20 houses on the four islands, a fish farm and about 40 to 50 weekend cottages. The islands are interconnected by electric grid with one connection to the mainland by an outdated sea cable, owned by Trønder Energi. It is estimated to last for about 5 years still, creating some urgency to find, test and evaluate alternative solutions. The cost of replacing the sea cable is deemed too high. Diesel power generation is today the immediate choice for a solution for these islands. However, the cost of transporting diesel fuel to the islands and the status of the islands as natural reserve do not support this choice.

The planning process for renewable energy (PV + wind) production on the islands has started. The PV is expected to be installed in 2018, and the wind energy is expected to follow shortly after. With dark Norwegian winter months and occasional consecutive days without wind, there is a need for storage to become self-sustainable with local renewable energy. The hydrogen-based energy storage may allow to meet the targeted values of RES > 95% and Power Availability > 98%. The main objective is to establish the peak-shaving capabilities arising from the local power demand, while ensuring an optimum use of non-programmable renewable resources. End user of the solution is the utility Trønder Energi (TE).

Figure 10. Map illustrating the geographical location of Froan

The plan is to establish maximum 2 500 m^2 PV and a 600 kW wind turbine (permission pending) on the islands and to keep the interconnecting grid, once the sea cable to the mainland ceases to exist. The foreseen plant specifically designed for the islands is planned to consist of a 50 kW electrolyser from Hydrogenics, about 100 kg steel tank H_2 storage (for some days of autonomy) and a 100 kW fuel cell system from Ballard Europe. Detailed design of the system and the control system will be part of the project. The control system will be able to determine the optimal energy and storage utilization and to optimize the small local network with respect to losses and/or voltage stabilization.

The non-integrated P2P solution enables the islands to become fully independent of shipped-in fuel. It allows for the optimized utilization of the local RES and secures supply all year round without polluting air or water and without disturbing the fragile wildlife and plants on the islands.

An initial test site at Rye on the mainland will consist of a micro-grid connecting two farms with a wind turbine and hydrogen-based energy storage.

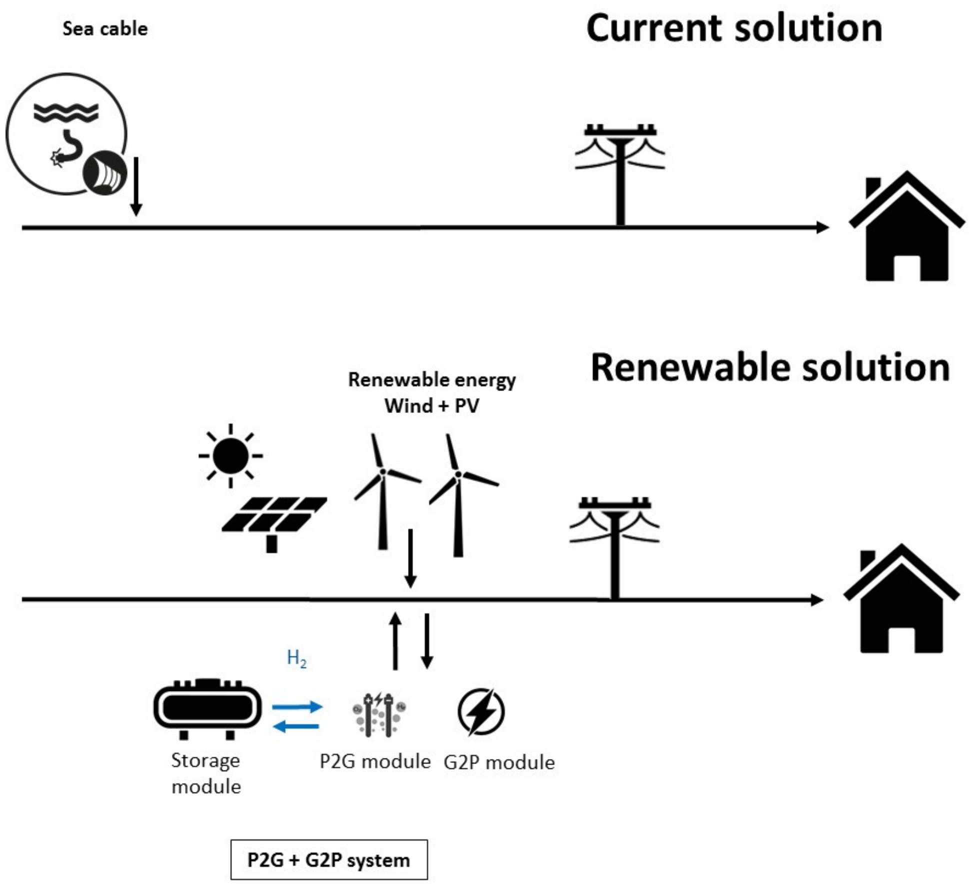

Figure 11. The current and renewable solutions for the Froan demo site

2.5 Summary

Demo site	1. Ginostra	2. Agkistro	3. Ambornetti	4. Froan (+ Rye)
Load typology	Residential	SME	Residential	Residential + SME
Grid connection	Off grid	Weak / unstable	Off grid	Reliable, outdated
A. Current solution	Diesel generators: 3 x 48 kW + 160 kW	--	--	Grid connection via sea cable
B. Alternative solution	--	20 km cable connection to unstable grid	Costly and invasive cable connection to grid or diesel generators[1]	Diesel generators[1]
RES	PV	Hydro	PV + biomass	PV + wind
	165 kW PV; 200 kW / 600 kWh Li-Ion battery	0.9 MW	40 kW PV; 50 kW CHP (biomass)	600 kW wind; PV to be designed

[1] Not detailed out as this is not a viable choice

C. Suggested innovative solution	Integrated P2P system	Integrated P2P system	Integrated P2P system	Non-integrated P2G+G2P system
P2G	50 kW	25 kW	25 kW	50 kW
G2P	50 kW	50 kW	50 kW	100 kW
Storage	2 000 kWh	1 000 kWh	500 kWh	About 3 000 kWh
Supplier	EPS	EPS	EPS	HYG, BPSE, POW

3 Economic framework

The economic and regulatory framework conditions have a large effect on the technical definitions and the potential economic revenues of a smart electric system relying on RES and storage. In the following, we describe the economic framework that forms the basis for the business models for the different demo cases in the REMOTE project.

3.1 Value proposition

The value proposition for the hydrogen-based systems varies between the demo case studies, although it is, in all cases, based on a long distance to a central grid and alternative power supply.

Grid connection

Ginostra and Ambornetti are completely off-grid today, and it will be very costly to get them connected to a central grid. For the Ginostra case, this is almost impossible given its island location and the costs of subsea cables, while for Ambornetti grid connection would be a very expensive solution. In the latter case, the nearest point of access is 400 meters below the demo site. In addition to the associated costs, this alternative would require invasive works and infrastructure.

The two remaining cases, Agkistro and Froan, have currently a grid connection. For Agkistro, the connection is weak and with low security of supply (requent power outages), while for Froan the grid connection is sufficient and reliable, but will need reinvestments within a relatively short time period. Given the ambitions of Agkistro to build an agrifood processing plant, it will be neccessary to either improve the grid connection or build a local solution based on hydrogen to supply the new plant. The former solution will be very costly, in terms of both investments, added taxes and power (the annual electricity costs are estimated to be more than 10 000 €/year). For the Froan case, replacing the subsea cables will be a large investment for TrønderEnergi, and the alternative of constructing a microgrid with hydrogen as a means for balancing the grid could be a viable business opportunity.

For all four cases in the REMOTE project, the grid connection is an important part of the value proposition for the hydrogen system. For the Ginostra case, the lack of availability of a connection is a given premise for the business case, while for the remaining three cases, the large costs of either investment or reinvestment give a high benchmark cost that allows for a potentially cost-efficient solution by using a hydrogen system.

There are large variations in electricity prices between the countries. In Italy, the electricity prices are similar all over the country and people at Ginostra, for instance, pay the same price for electricity as the people on mainland Italy. The extra costs due to high generation prices at Ginostra are covered by a component of the energy bill, called UC4, that basically covers the major costs of energy systems expenditures on Italian small islands. In Norway, the net tariff costs vary between regions, making the most expensive regions (especially in the northern and western parts of the country) more suitable for off-grid solutions.

Current solution / benchmark
At the demo site in Ginostra, current power demand is met by production from diesel generators. Due to the remote location of the island, the fuel must be imported by helicopter, leading to very high costs of providing the power. The final generation cost is estimated to be more than 600 Euro per MWh. Additionally, the use of diesel generators leads to CO_2 emissions of approximately 166 tons per year. At Froan, power is currently supplied by a connection to the central grid which is a cost-efficient and, given the fact that power production in Norway is almost 100% renewable energy, environmentally friendly solution. One of the alternatives being considered at Froan, in addition to replacing the subsea cable, is a system similar to the one currently in use in Ginostra. Changing to diesel generation when the sea cable can no longer be used, is today the immediate choice for a solution for these islands. However, the cost of transporting diesel fuel to the islands and the status of the islands as a natural reserve do not support this choice. Nevertheless, it may be an interesting benchmark for further analysis of the hydrogen system.

In Agkistro, the present solution is not suitable for providing reliable energy to the new processing building. The most natural benchmark in this situation is the cost of building a separate connection line for the new investment. A separate line must be built, linking directly to another high-voltage transformer 20 km away. This leads to large investment costs, and additional taxes (building ownership, municipal costs, other service taxes). Additionally, the value of the sold hydropower energy is 0,084 €/kWh, while the value of purchased energy from the network can reach 0,20 €/kWh due to the extra charges.

The demo case in Ambornetti does not have an existing system to compare with since it has never been connected to the grid and has been abandoned until recently. Here, a hypotetical investment in diesel generators may serve as benchmark.

Supply and demand at the demo sites
The supply of power at the demo sites is volatile and depends on weather conditions such as inflow, radiation and wind conditions. Also the demand will be volatile and have fluctuations over days and weeks in the different seasons. The volatility in both supply and demand gives rise to the need for storage in order to utilize surplus production of power as well as to supply power when demand is higher than supply from renewable power production. Figure 12 illustrates this for a typical day in July for the demo site in Ambornetti. In the period from midnight until 7 o'clock in the morning, there is a deficit of 17,8 kWh, in the period between 7 and 17 o'clock there is a surplus of 217,9 kWh, while in the last period, between 17 and 24 o'clock, there is a deficit again of 101,3 kWh. With an available energy storage, such as a hydrogen system with an electrolyser, a hydrogen storage and a fuel cell, it is possible to balance this pattern by producing power in the fuel cell in the first period, producing hydrogen with the electrolyser in the second period, and then using the fuel cell again in the last period of the day. Utilizing the storage for such balancing increases both the security of supply and the utilization of renewable energy at the site. This is particularly important for remote areas where the grid connection is either weak or non-existent. The actual dimensioning of system components will be analyzed in more detail within the REMOTE project, and will depend on site characteristics such as production potential of renewable energy, load profiles, uncertainty in profiles, costs and the potential for utilizing by-products from the hydrogen production. Figure 13 shows load and supply profiles for the demo site Rye for the period of 22nd to 24th April 2017. The pattern of supply is very different from Ambornetti, but also in this figure it is evident that there is a potential for balancing supply and demand using an energy storage. An overview, with full load and supply profiles for the four demo sites, is included in Appendix A.

Other market possibilities
The production of hydrogen for balancing purposes in remote areas may provide a possibility for additional value creation linked to either utilizing the hydrogen for other purposes or utilizing the byproducts oxygen and heat locally. Currently, there is, however, not much potential for additional market possibilities besides using the hydrogen for balancing and power supply. In Agkistro, the heat

will be utilized at the site, and in Froan there might be a future possibility of using the oxygen for fish farming.

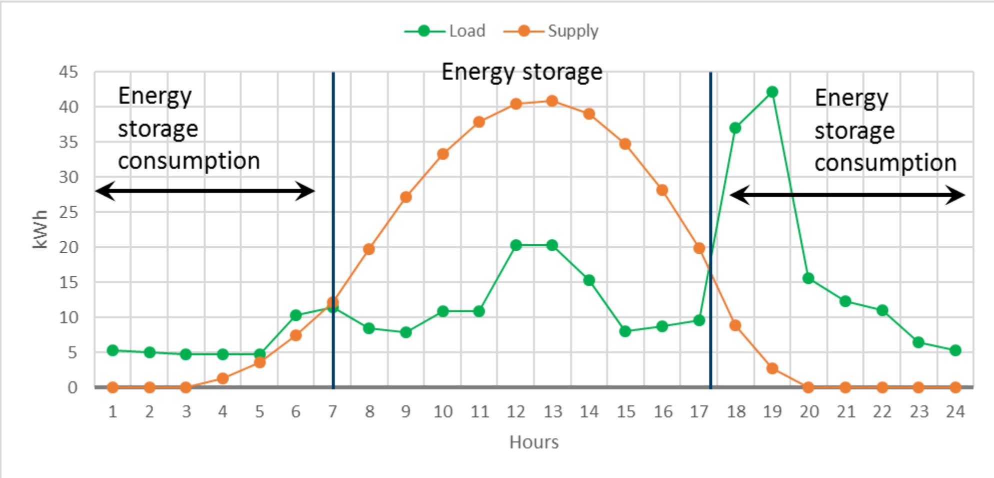

Figure 12. Demo 3 Ambornetti. Modelled energy supply (PV) and load and potential for utilization of energy storage for a representative day in July

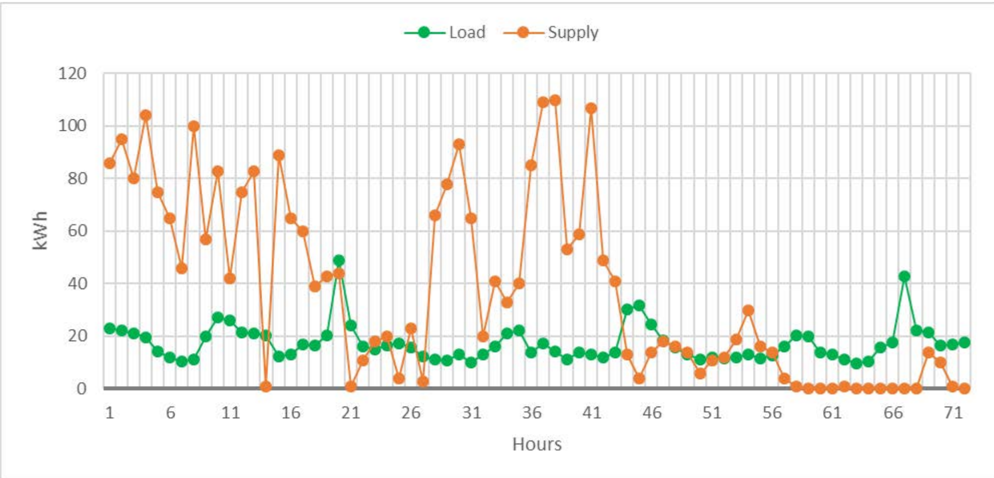

Figure 13. Demo 4 Rye. Energy supply (wind) and load, 22 – 24 April 2017

3.2 Economic benefits: cost comparison

Building on preliminary data for the demo sites, we compare costs for the current or alternative and the suggested renewable solutions to outline potential economic benefits in the single cases by way of net present costs. We assume that a (re-)investment for the current or alternative solution (replacing the generator set, constructing a new connection to the grid, investing in a diesel generator set, replacing the sea cable) would have to be made at the start of the considered period, i.e., at the same time an investment in the suggested renewable solution would be made. We received preliminary investment, re-investment and operational cost estimates for the four demo sites from the project partners. However, due to confidentiality reasons, these details have been omitted from the final version of this report. For both solutions, we calculate net present costs over a time horizon of 10, 20, 25, and 30 years, respectively, shown in tables 1 – 4 and figures 14 – 17. We use a nominal discount rate of 7 % and adjust for inflation with an assumed rate of 2 % p.a., such that the real discount rate is 4,9 %. In addition, the tables show average costs per MWh load, under the assumption that the given yearly loads remain unchanged over the considered time horizon.

Demo 1. Ginostra

Table 1. Net present and unit costs for current and suggested solutions (yearly load:171,6 MWh (2015))

Duration (years)	Current solution (replacing diesel generator set)		Suggested renewable solution (PV + P2P)	
	Net present costs	Unit costs	Net present costs	Unit costs
10	1 117 328 €	651,31 €/MWh	1 525 886 €	889,47 €/MWh
20	1 777 852 €	518,17 €/MWh	1 778 405 €	518,33 €/MWh
25	2 015 048 €	469,84 €/MWh	1 882 085 €	438,84 €/MWh
30	2 188 679 €	425,28 €/MWh	1 934 885 €	375,96 €/MWh

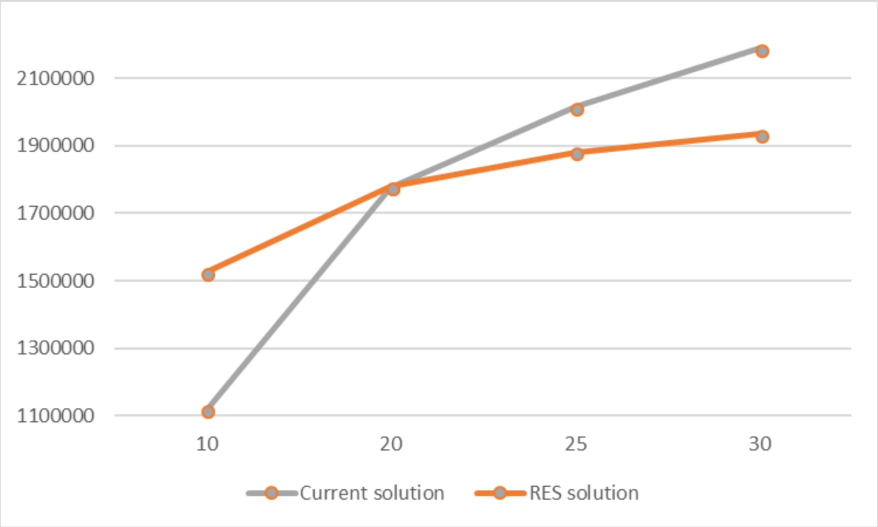

Figure 14. Demo 1 Ginostra. Net present costs for current and suggested solutions

Demo 2. Agkistro

Table 2. Net present costs and unit costs for alternative and suggested solutions (estimated yearly load: 129 MWh)

Duration (years)	Alternative solution (cable connection to grid)		Suggested renewable solution (P2P)	
	Net present costs	Unit costs	Net present costs	Unit costs
10	1 114 690 €	864,10 €/MWh	528 986 €	410,07 €/MWh
20	1 309 696 €	507,63 €/MWh	632 255 €	245,06 €/MWh
25	1 377 310 €	427,07 €/MWh	668 061 €	207,15 €/MWh
30	1 430 536 €	369,65 €/MWh	696 248 €	179,91 €/MWh

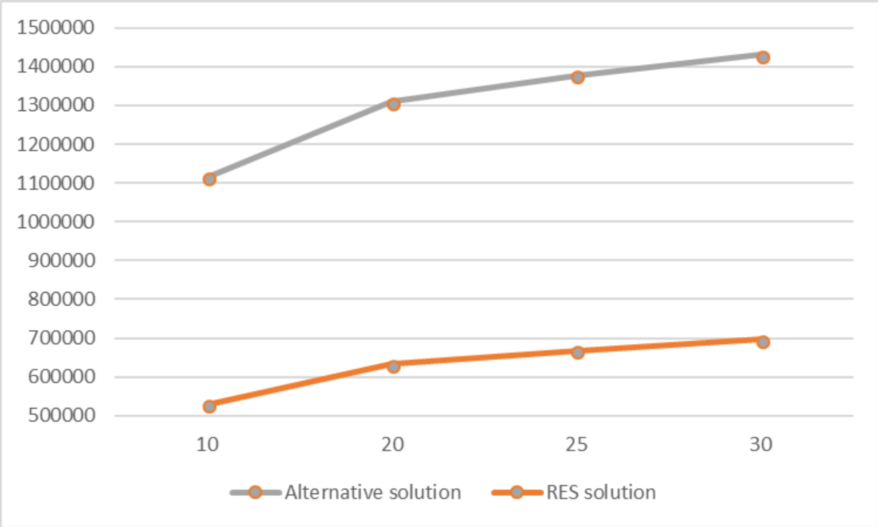

Figure 15. Demo 2 Agkistro. Net present costs for alternative and suggested solutions

Demo 3. Ambornetti

Table 3. Net present costs and unit costs for alternative and suggested solutions (estimated yearly load: 100 MWh)

Duration (years)	Alternative solution (hypothetic diesel generator set)		Suggested renewable solution (PV + biomass + P2P)	
	Net present costs	Unit costs	Net present costs	Unit costs
10	583 298 €	583,30 €/MWh	820 675 €	817,08 €/MWh
20	939 686 €	469,84 €/MWh	972 659 €	484,20 €/MWh
25	1 091 472 €	436,59 €/MWh	1 029 387 €	409,95 €/MWh
30	1 160 530 €	386,84 €/MWh	1 066 839 €	354,06 €/MWh

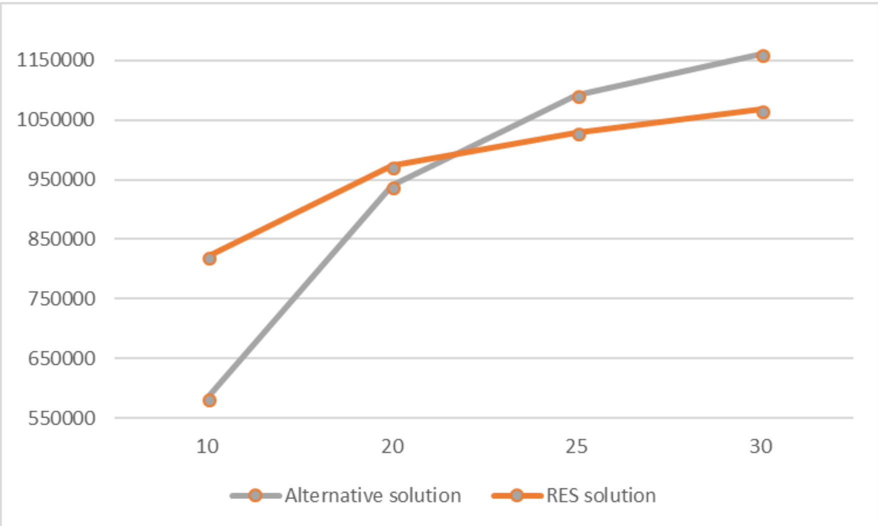

Figure 16. Demo 3 Ambornetti. Net present costs for alternative and suggested solutions

Demo 4. Froan

Table 4. Net present costs and unit costs for current and suggested solutions (estimated yearly load: 795,6 MWh)

Duration (years)	Current solution (replacing sea cable)		Suggested renewable solution (Wind + PV + P2G + G2P)	
	Net present costs	Unit costs	Net present costs	Unit costs
10	3 241 974 €	407,49 €/MWh	3 006 252 €	377,86 €/MWh
20	3 329 951 €	209,27 €/MWh	3 258 183 €	204,76 €/MWh
25	3 360 456 €	168,95 €/MWh	3 345 534 €	168,20 €/MWh
30	3 384 469 €	141,80 €/MWh	3 414 297 €	143,05 €/MWh

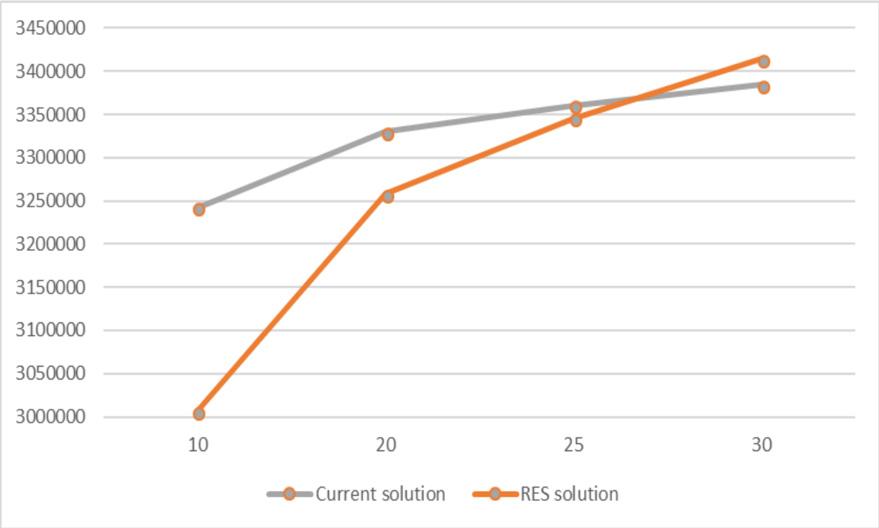

Figure 17. Demo 4 Froan. Net present costs for current and suggested solutions

Evaluation

Evidently, the suggested renewable solutions can be economically viable, either immediately or in the long run. This is facilitated by, among others, a life time of the renewable generators (PV) of over 20 years. For Ambornetti (demo case 3), the estimates show that the renewable solution may be more cost efficient first after a longer period. However, note that the simplified example analyses here are based on preliminary cost assumptions with a limited scope. For example, somewhat higher maintenance costs for the alternative solution or a lower discount rate would tip the scales towards the renewable solution. For Froan (demo case 4), the high up-front investment cost of the sea cable carries a clear financial and budget risk compared to the more distributed cost pattern of the H_2 solution. Moreover, the latter provides more flexibility with respect to future demand development as the equipment can be relocated and reused elsewhere. Also potential revenues and other market possibilities have not been taken into account in these preliminary analyses. This underlines the necessity of detailed and comprehensive techno-economic analyses to provide more realistic guidance. Such analyses will be performed at a later stage of the REMOTE project.

In addition to economic efficiency, environmental advantages of the suggested RES solutions should not be ignored in the analysis. They may enter techno-economic considerations in terms of savings, e.g., avoided penalties for CO2 emissions, but are largely of less tangible nature.

3.3 Summary

Demo site	Grid connection	Main drivers / advantages of proposed solution
1. Ginostra	Off grid	Prohibitively high cost of grid connection; high cost of energy generation from fossil fuels; independence of fossil fuels
2. Agkistro	Weak / unstable	High cost of grid connection and high energy costs / uneconomic tariffs; stable energy supply and efficient use of excess energy from RES
3. Ambornetti	Off grid	Very high cost of grid connection; invasive works and infrastructure; minimization of lifecycle impact – neutral impact on environment
4. Froan	Reliable, outdated	Very high cost of updating existing grid connection; use of fossil fuels for energy generation not viable, would entail high costs

4 Regulatory framework

From a business perspective, the absence of energy storage-specific regulation may represent a major risk for the operators and users of the installation sites. Permisions for the installation sites may depend on and conform to rules developed for other/different operations or substances and may represent a legal barrier. To minimize this risk, there is a need to provide the operators and users with a clear view of the applicable regulations whilst calling the attention of policy makers to legal barriers to be removed.

Progressive regulation is, however, currently being developed in many EU countries for energy storage and access to market, but there are still many gaps to fill. For instance, in Italy there is not a defined regulatory framework concerning energy storage systems coupled with renewable energy sources. The Decision 300/2017, however, represents an initial step towards storage system development, as it defines the criteria for renewable power plants (less than 10 MW) to provide grid services. In particular, the renewable generation assets must be coupled with energy storage systems. Regulations for renewable power plants with generation capacity higher than 10 MW are still under development. The Ministry of Economic Development still has much work to do on the regulatory framework in order to promote the utilization of storage systems coupled with renewable energy to provide grid services, although the Ministry with the ”DM 14 Febbraio 2017” aimed at fostering renewable systems development on Italian islands. This is a call to promote the development of two pilot projects that integrate energy storage systems to increment the renewable energy penetration in remote small islands not connected to the national grid.

In Greece, until now there has been a lack of awareness of the strategic importance of energy storage, resulting in a lack of regulatory framework for the sector. The Greek Regulatory Authority for Energy has, however, recently published their proposals for a new regulation and the Ministry has now proposed to accelerate the final approval and the issue of the related legislation.

In Norway, there is an increasing interest for distributed energy systems, mainly driven by the need for large investments in the distribution power grid within the next decade. In total, the investments are estimated to be about 16 billion Euro. This need for investments is driven by the increasing use of high-load equipment, such as chargers for electric cars or induction ovens, and increased portions of non-regulated renewable energy sources. Microgrids can be an alternative to fulfil the Energy Laws obligation to secure electricity delivery to all Norwegian households, meeting the conditions of i) energy security of the microgrid system for rural areas of more than 98%, and ii) a renewable portion of energy delivery for the whole of Norway of more than 95%.

To gain insights into the regulatory framework affecting the demo sites, we collected information from the REMOTE partners for each demo site.

4.1 The permitting process

The permitting process is geographically dependent and may differ within the various countries. In general, the municipalities are responsible for permitting land use according to their master plans while various entities are responsible for permitting installation and operation. An example of the permitting process for demo site 4 (Froan / Rye) is illustrated in Figure 14.

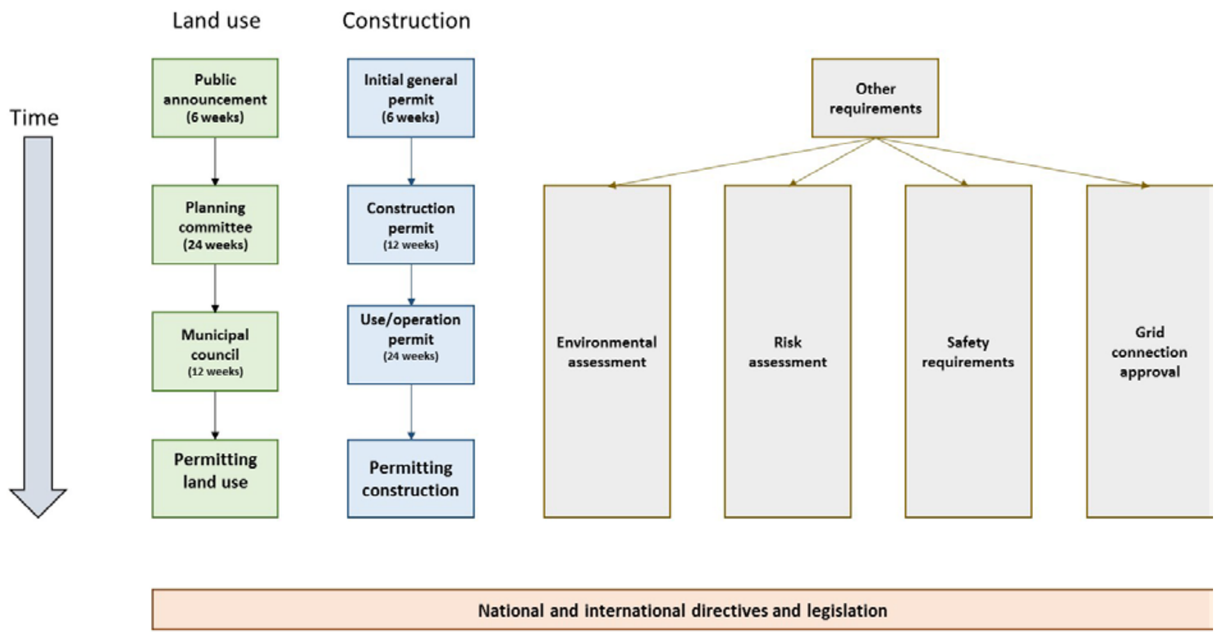

Figure 18. The permitting process as exemplified for demo site 4 (Froan / Rye).

Demo 1. Ginostra

Constructing the Ginostra power plant installation requires a permit from the Municipality of Lipari (ME), according to its Master Plan. The permit is required for the entire hybrid power plant, and not only for the hydrogen generator. A power plant is already installed in the same area selected for the installation of the hybrid plant and the main constraint is related to the minimum distance (20 m) of the hydrogen production plant from surrounding streets according to the Ministrial Decree from 31 August 2006. The municipality of Lipari is responsible for delivering the land use permit, which is required for the entire hybrid power plant.

The Sicily Region – Assessorato Energia E Dei Servizi Di Pubblica Utilita' - Dipartimento Energia is the main autority for permitting the hybrid plant (including P2P).

Other entities involved in the authorization process comprise the following:

- Sicily Region – Assessorato Dell Energia – Dipartimento Acque e Rifiuti
- Ministry of Economic Development – Dipartimento Comunicazioni – Ispettorato Territoriale Sicilia
- Sicily Region – Assessorato Territorio e Ambiente VAS-VIA
- Sicily Region – Assessorato Territorio e Ambiente Servizio III Urbanistica
- Sicily Region – Assessorato Infrastrutture E Mobilita – Genio Civile
- Sicily Region – Soprintendenza dei Beni Culturali e Ambientali Della Provincia di Messina
- Provincia Regionale di Messina
- Municipality of Lipari
- ASP Messina
- ARPA Dipartimento Provinciale
- e-distribuzione DTR Sicilia (DSO)
- Ente di gestione dell'area protetta
- Civil Aviation (ENAC/ENAV)
- Local Fire Department

For the hydrogen facility, the main authorization (fire risk assessment) was provided by the Local Fire Department. This authorization is included within the single authorization process (called "AU Autorizzazione Unica") requested in accordance to Legislative Decree n. 387 ofl 29/12/2003 and related to the authorization of the entire hybrid power plant. The following authorizations are included into a single authorization procedure:

1. *Environmental authorization* according to legislative decree “18 Febbraio 2005 n. 59”, with full implementation of the 96/61/CE Directive.
2. *Landscape authorization* according to art. 146 of the legislative decree 42/2004 and s.m.i.
3. *Environmental impact assessment* according to the second section of the legislative decree 152/06. This shall be sent to Regione Sicilia.
4. *Authorization for greenhouse gasses emissions in the atmosphere* according to the fifth section of the legislative decree 152/06. This shall be the sent to the Municipality of Lipari.
5. *Authorization for waste management* according to the fourth section of the legislative decree 152/06. This shall be the sent to the Municipality of Lipari.
6. The *“go-ahead”* from the Management Bodies of the protected area (under analysis), according to the law “6 dicembre 1991”, n. 394.
7. *Construction permit* according to DPR 380 of 2001, which is released by the Municipality of Lipari.
8. The *project conformity approval* by Local Fire Department according to the relevant fire safety legislation, according to art. 2 of DPR 12 January 1998, n. 37.
9. The *“go-ahead”* from the Armed Forces (Army, Navy, Air Force) for military constraints and for flight safety at low altitude if needed. The “go-ahead” is required only if the power plant will be located nearby areas with military restrictions (not needed for Ginostra).
10. *Hydrogeological assessment approval* introduced by R.D. 30 dicembre 1923, n. 3267, according to art. 61 (5) of the legislative decree n. I 52/06.
11. *Seismic assessment approval* according to law 2 February 1974, n. 64 and subsequent implementing acts.
12. Flight safety “go-ahead” released by Civil Aviation (ENAC/ENAV), according to R.D. 30 March 1942, n. 327, which lays down the Codice della Navigazione.
13. The *change of the temporary or definitive land use* plan of the (demo site) land area, according to law 1766 of 1927 and subsequent modifications.
14. *Authorization to cutting down trees* according to Regional Laws.
15. *Noise emissions assessment* within the limits allowed according to law 447 of 1995 and subsequent changes and integrations.
16. The *“go-ahead”* released by the Ministry of Economic Development according to Art. 95 of the legislative decree 259 of 2003.
17. *Authorization for the streets crossing and utilization* according to the Highway Code.
18. Waste disposal authorization released by Municipality of Lipari according to the legislative decree 152 of 2006.
19. *Non-interference* with the mining activities of power plant construction and related electrical connection lines, according to Art. 120 del R.D. n. 1775/1933.

The time frame of permitting is minimum 6 months and depends on the number of integration / modification requests.

Demo 2. Agkistro

In Greece, an industrial facility requires a permit from the relevant municipality, according to the Greek Planning and Building Act. The Urban Planning Service certifies the allowed land uses for a requested area and whether the proposed activity is allowed. The proposed change for the official land use plan of the country should be done only by official public services or departments and no private entity can apply.

In general, the process for industrial facilities requires:

1. Building permit from the Urban Planning Service.
2. Permit of installation from the local Regional Unit.
3. Permit of operation from the local Regional Unit.
4. Certification from the Fire Department. The request to the Department is submitted in advance of the installation. For the certification to be issued, the Department will carry out a site inspection after the installation.

For industrial facilities, environmental and fire safety aspects must be considered for the installation permits to be issued. The local Regional Unit will also carry out a site inspection before issuing the permits.

Demo 3. Ambornetti

The production of hydrogen requires a permit from the Municipality of Ostana, according to its Master Plan. If the plant supplies more than one building, it must be installed in specific service / plants areas identified in the Master Plan. Storage of the hydrogen must comply to the regulation establishing a minimum distance from hotels to be guaranteed for storing hydrogen, 20 + 10 metres (DM 24-11-1984).

For connecting the electrolyser to the grid, the national body in charge of the electricity distribution is called "E-Distribuzione", also looking after the connection of the generator plant to the grid. The connection procedure and requirements are unknown at the moment. These are disciplined through the Authority for the Regulation of Energy Network and Environment (ARERA) through communication AEEGSI ARG/elt n. 99/2008.

To change the land use plan, a specific procedure is required (Variation to the Master Plan) that can take up to 16 months. This includes a presentation of the preliminary project with the Proposal of Variation to the municipality, a conference to the Piedmont Region about the Proposal of Variation, approval of the Variation by the conference of services (local authorities from region to district level, planning authorities with landscape, heritage remit).

For the permitting process, the following are required:

1. Submit Project and ask Permit to Fire Department (VVF) (60 days)
2. Submit Project and ask Permit to Municipality (30 days)
3. After the construction, there will be a site inspection from the Fire Department

For hydrogen storage, permitting requires:

1. Presentation and discussion of the project with the Fire Department to obtain the authorization
2. Delivery of the project (including the Fire Permit) to the Municipality of Ostana

The types of permitting include both a permit from the fire department and a building permit. There is no country-wide rule about the issue, which is rather new. Obtaining a fire permit takes 60 days, while the municipality permit takes 30 days. The permitting procedures are the same as, e.g., for a biogas plant.

Demo 4. Froan (and Rye)

Developing a land use plan for hydrogen production and hydrogen storage requires a permit from the relevant municipality (here: Frøya), according to the Norwegian Planning and Building Act. In case more than 5 tons of hydrogen are stored, the Major Accident Regulation will come into act, which will require a special consent from the Directorate for Civil Protection (DSB).

There are no specific requirements or zone prohibitions for hydrogen production facilities in the land use plans. General rules for inflammable, reactive and pressurized substances apply. Storage of substances such as hydrogen is not allowed in catering, accommodation or assembly buildings, unless special steps have been taken. Enterprises with hydrogen storage facilities must seek permission from the relevant municipality, the same way as operators of other hydrogen facilities.

For connection of an electrolyser to the electricity grid, the Norwegian Water Resources and Energy Directorate (NVE) has the overall authority and is the responsible authority / legal entity. Statnett SF has the role of Transmission System Operator (TSO), meaning that it approves the technical design of generators, network units and industry connections, before units may connect to the transmission and higher voltage distribution grids.

For land use plans in public zones, a thorough assessment and documentation is required, but the permit process is generally smooth. The proposed change shall be announced publicly and shall be open for a minimum of 6 weeks, for reactions / feedback from relevant stakeholders. Then, the proposal is placed before the planning committee, which should handle it within 24 weeks. After processing by the committee, the proposal shall be presented for decision by the municipal council, within 12 weeks. In all, this implies that a change should not take more than 42 weeks. This is the same procedure as for facilities for processing or production of other inflammable substances.

The municipality is responsible for the permitting requirements for facilities storing less than 5 tons of hydrogen. The process has 3 steps:

1. An initial general permit.
2. A permit to start construction, before work to construct the facility can begin.
3. A use or operation permit is required, before the actual production of hydrogen.

The main requirements with their applicable regulations for building a hydrogen production facility (e.g. permitting regime, agreement) apart from the land use planning include:

1. Environmental assessment (e.g., emissions (IED), noise) - regulated under the national Pollution Control Act (Forurensningsloven).
2. Risk assessment - Installations of less than 5 tons may apply for general permission, construction and operation permits directly from the relevant municipality.
3. Safety requirements, including internal / external safety distances – for tank storage above 5 tons, information is required as part of the notification includes details on tank placement, special activities relating to the operation, information about the tanks / caverns / vessels for storage, type and amount of inflammable substance.

All aspects, environmental, risk, safety, etc., should be considered. The local fire and rescue agency is consulted in most cases.

Facilities for hydrogen production are subject to the same requirements as other facilities for production or handling of inflammable substances, according to the Fire and explosion protection Act. Thus, a quite comprehensive risk assessment must be carried out before the first application is submitted.

The process of notification requires the enterprise to register and submit the required information electronically (through a national web portal for electronic dialogue between the business / industry sector, citizens and government agencies in Norway). The information is channelled through to the municipal administration.

The time frame for permitting includes the following:
1. Maximum response time for initial, general permit: 6 weeks.
2. Construction permit: 12 weeks.
3. Operation permit: 24 weeks.

Generally, electrolysis is exempt from taxes. Electrolysis for energy supply can be supported via the electricity certificate scheme (a Norwegian-Swedish collaboration to increase renewable energy production).

4.2 Applicable European and national directives and legislation

Applicable European directives and legislations are listed in Table 3.

Table 5. Applicable European directives and legislation

Directive/legislation	Short description
ATEX Directive 2014/34/EU	Covering equipment and protective systems intended for use in potentially explosive atmospheres. Not specific to hydrogen but referring to any fuel that is capable of generating a flammable atmosphere.
Pressure Equipment Directive (97/23/EC)	For the manufacture and conformity assessment of pressure equipment that is subjected to an internal pressure greater than 0.5 bar above atmospheric pressure.
GAD - Gas Appliances Directive	For appliances burning gaseous fuels.
Machinery Directive (Supply of Machinery Safety Regulations)	Applies to machinery and safety components. This would not apply to the fuel cell installation itself, but may apply to associated equipment required for operating the installation.

Demo 1. Ginostra

The following national legislative / administrative processes are applicable:

- The Master Plan of Lipari, for land use
- DM (Ministerial Decree) 31/08/2006; DM 03/08/2015, for fire prevention
- DM n. 329, for the use of pressure plants
- DPR (Presidential Decree) 126/98 ATEX, to prevent explosion risk

Demo 2. Agkistro

The following national legislative / administrative processes are applicable:

- Certification for land use for specific area, issued by the Urban Planning Service
- Presidential Decree 71/1988 (Articles 11 & 1-4) for Passive Fire Protection and the Joint Ministerial Decision Φ15/1589/2006 for Active Fire Protection
- Joint Ministerial Decision172058/2016 for the "Definition of rules, measures and conditions for dealing with risk management of major accidents in plants, because of the existence of dangerous substances, in compliance with the Directive 2012/18/EU "to address the risks of major accidents related with dangerous substances and for modification and the repeal of Directive 96/82/EC of the Council "of the European Parliament and of the Council of 4 July 2012"

Demo 3. Ambornetti

The following national legislative / administrative processes are applicable:

- Master Plan of Ostana, for land use
- DM (Ministerial Decree) 31/08/2006; DM 24/11/1984, for fire prevention
- DM n. 329, for the use of pressure plants
- DPR (Presidential Decree) 126/98 ATEX, to prevent explosion risk

For hydrogen storage, the main requirements from DM 24-11-1984 are:

- An enclosure for safety requirements
- Internal safety distance
- External safety distance (20+10 metres at all from hotels)
- Ventilation must be guaranteed for the building that holds the storage

Demo 4. Froan (and Rye)

The national level framework includes the following:

- Planning and Building Act (2008).
- Control of Major Accident Hazards Involving Dangerous Substances, Regulation (2016)
- Fire and Explosion Prevention Act
- Regulation on handling of inflammable, reactive and pressurized substances, and equipment and facilities used in the handling of such substances (2015)
- Guidelines, application for special consent, the Norwegian Directorate for Civil Protection

5 Conclusions – why to develop the demos

It can be concluded that the main driver for the business cases at the four demo sites varies from reducing electricity costs and emissions in the current situation to avoiding costly investments for maintaining, replacing or strengthening the grid connection. Each site has also a strong ambition to be supplied by fully renewable power. In the following, a short summary of the main drivers is presented.

For the Ginostra site, the main motivation for replacing the existing system is improved quality of the electricity service, reduced costs of electricity supply and reduced local emissions. The prospect of demonstrating the possibility of a high level of renewable energy production has led to active involvement and interest from local authorities.

In Agkistro, the motivation for investing in a hydrogen-based system comes from both the high alternative cost of strengthening the connection to the central grid and the need to improve the quality of the current electricity supply. Lessons learned from this case can prove valuable for other remote areas in Greece, given their problematic connection to the central grid.

The case for Ambornetti is special in the sense that it will be designed during the project phase. The site had been abandoned for some time and does not have a grid connection. Given the location of the site, connection to the central grid is prohibited by both high costs and the need for invasive changes in the environment. The combined heat and power generator based on biomass will supply the site with both heat and power without the need for fossil fuel backup.

In Froan, the main motivation behind the hydrogen system is to avoid the high up-front costs of replacing the current subsea cable connecting the remote island to the central grid. Moreover, there may be incentives to avoid financial risk and the advantage of added flexibility. The most likely alternative solution is based on diesel generators, leading to high fuel costs (due to the substantial cost of transportation to the island) and high emissions. Hence, that solution is most likely not viable, given the islands' status as a natural reserve.

Indeed, another strong motivation for implementing the suggested RES solutions is environmental concerns. All demo cases stress the importance of being independent of fossil fuels or reducing their usage to a minimum. In addition, the energy generated by the RES shall be used as efficient as possible and the lifecycle impact of the systems to be installed shall be minimized as well. A thorough evaluation of this aspect has, however, not been part of the mandate of this report.

Legal-administrative barriers may represent an obstacle to a quick deployment of hydrogen demo installations. They may reflect a lack of acknowledgement of the key features of the installations within national legal codes and local planning by-laws, along with additional bureaucracy and complex sets of procedures and requirements. Legally, the P2P hydrogen systems are classified as an industrial plant operating inflammable substances. Installing and operating it requires today a significant number of permits and safety precautions. Timewise, getting to change land-use plans requires from weeks to several months and more than a year, while obtaining necessary permits for installation and operation requires additional weeks to several months.

Acknowledgements

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Planning and building act 2008. Lov om planlegging og byggesaksbehandling (plan- og bygningsloven). https://lovdata.no/dokument/NL/lov/2008-06-27-71

Appendix – Load and supply profiles

A.1 Demo 1. Ginostra

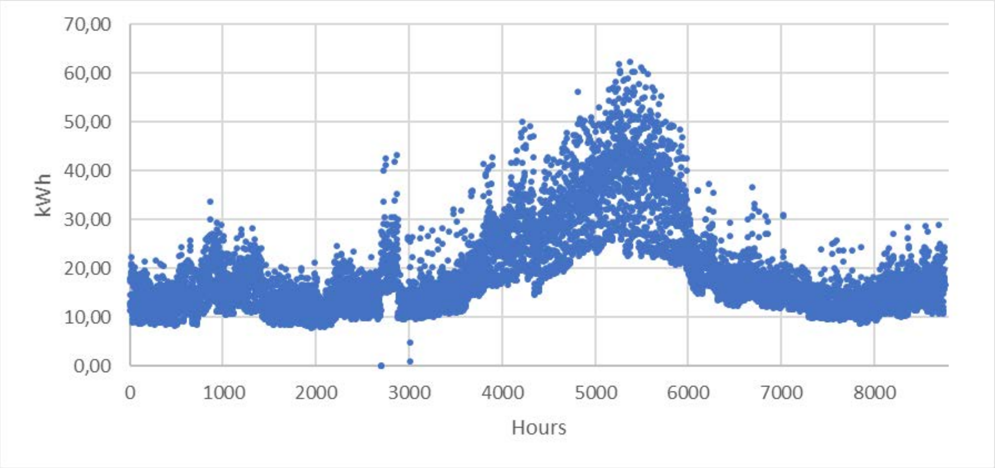

Figure 19. Load profile Demo 1 Ginostra: hourly loads (2015)

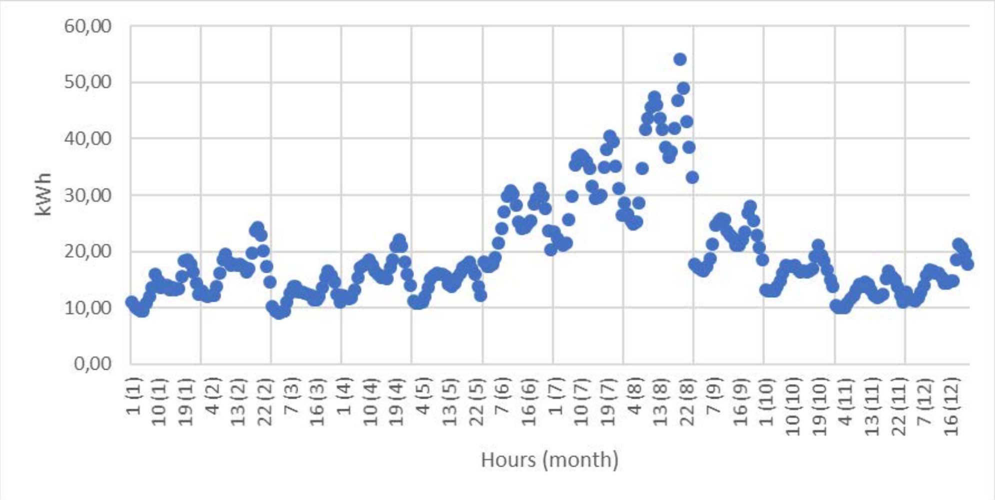

Figure 20. Load profile Demo 1 Ginostra: hourly loads for an average per month (2015)

A.2 Demo 2. Agkistro

For Demo 2 Agkistro, there is no current load. The expected load, when the processing facility has been built and is fully operational, will be a varying combination of energy demand from equipment (5 kW), heat pumps (32 kW) and drier (3 kW), i.e., a maximum of around 40 kW. This combination varies between seasons and over the working day: There will be 40 days in August and September and 50 days between December and February, where the load is expected to be at maximum due to drying and heat pump use, respectively. During 40 days in spring and fall, loads will be at minimum, while they will be around an average value else. For the working days, the loads will be at maximum from 8 til 16 o'clock and at the minimum else. However, on the days of drying, the drier will be working continuously, increasing the minimum load.

Current and expected supply from the hydro-electric plant is at, on average, 350 kW/h.

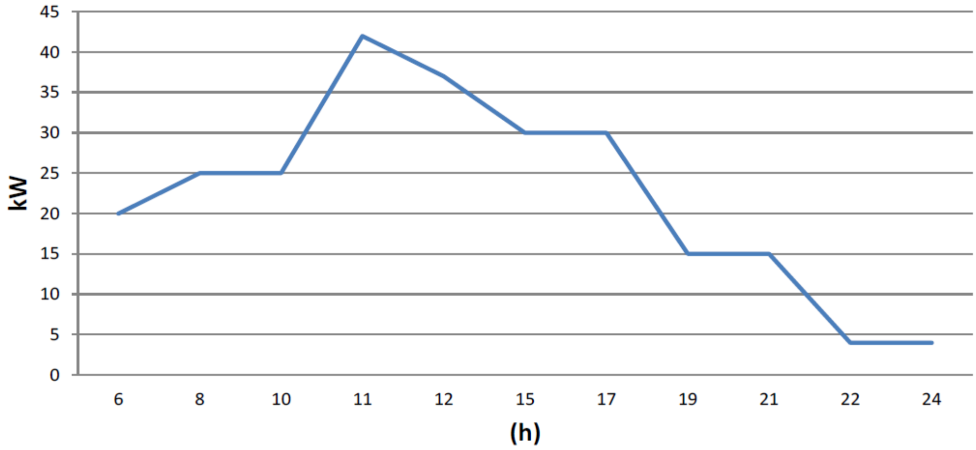

Figure 21. Load profile Demo 2 Agkistro: hourly loads for typical working day (expected)

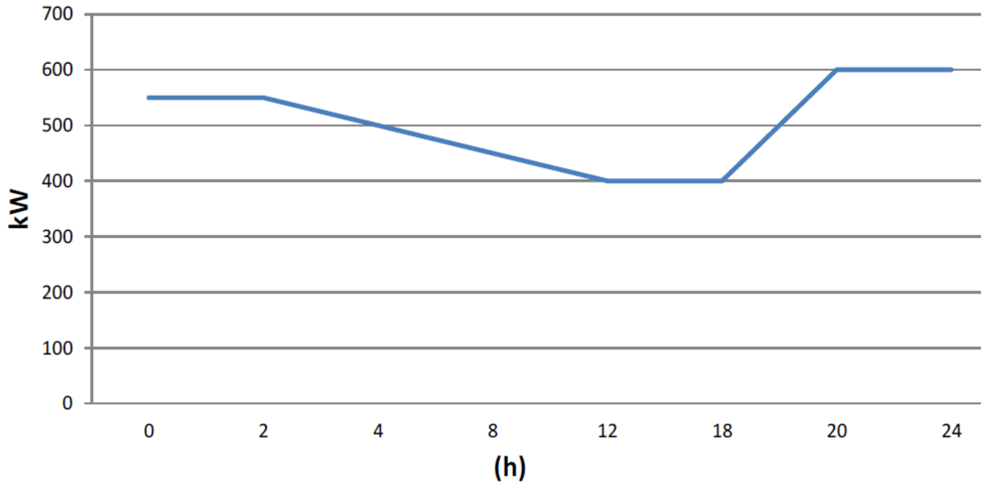

Figure 22. Supply profile Demo 2 Agkistro: hourly supply for a typical day

A.3. Demo 3. Ambornetti

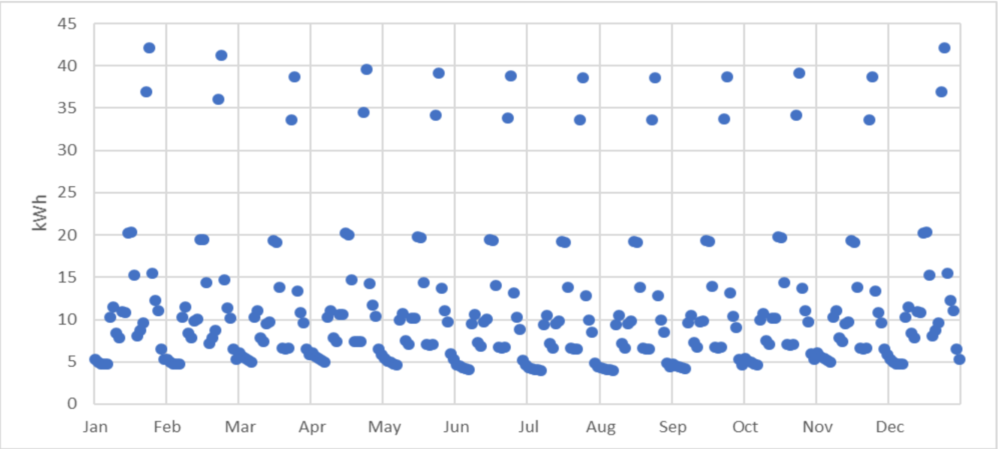

Figure 23. Load profile Demo 3 Ambornetti: hourly loads for an average day per month

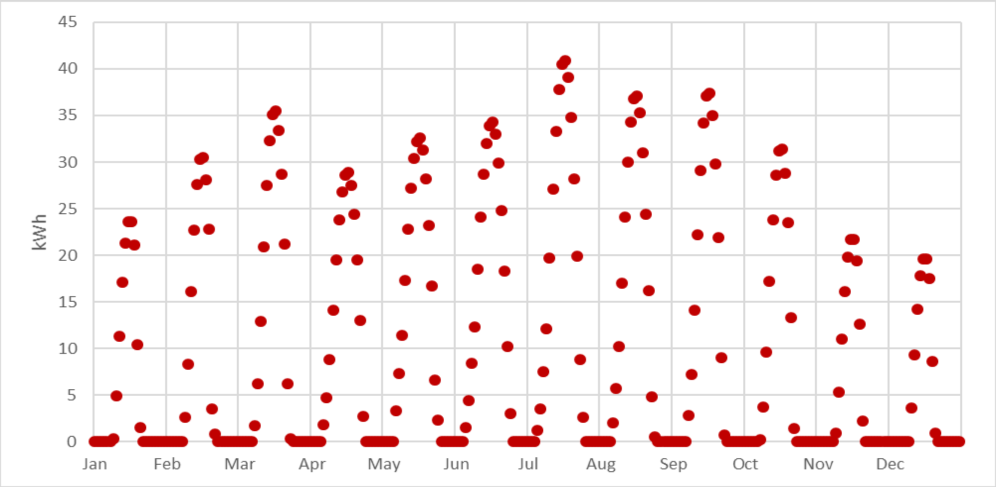

Figure 24. Supply profile Demo 3 Ambornetti: hourly supply for an average day per month

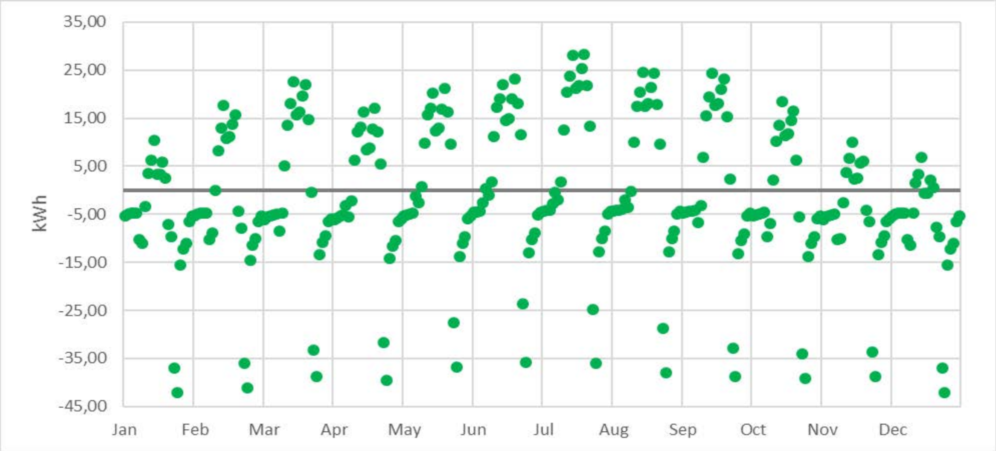

Figure 25. Discrepancy supply - load Demo 3 Ambornetti: hourly values for an average day per month

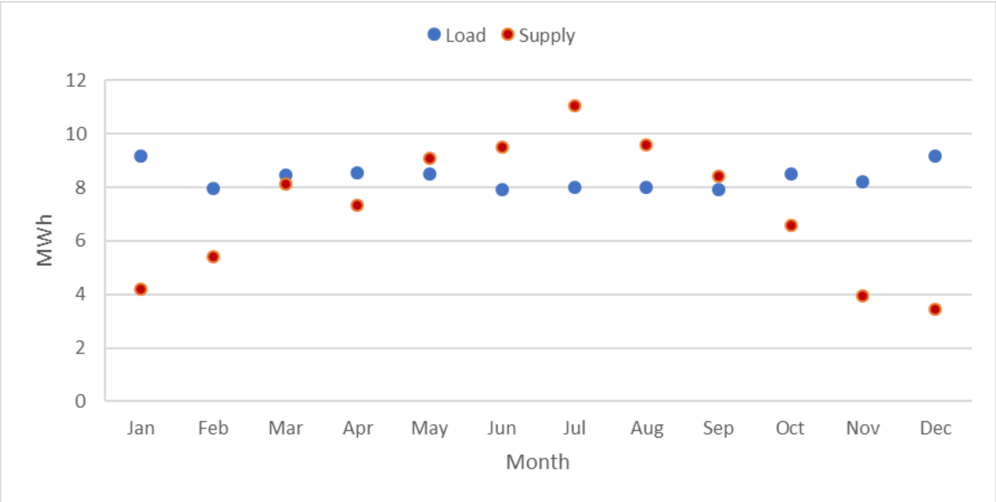

Figure 26. Load and supply profile Demo 3 Ambornetti: aggregated monthly load and supply

A.4. Demo 4. Froan / Rye

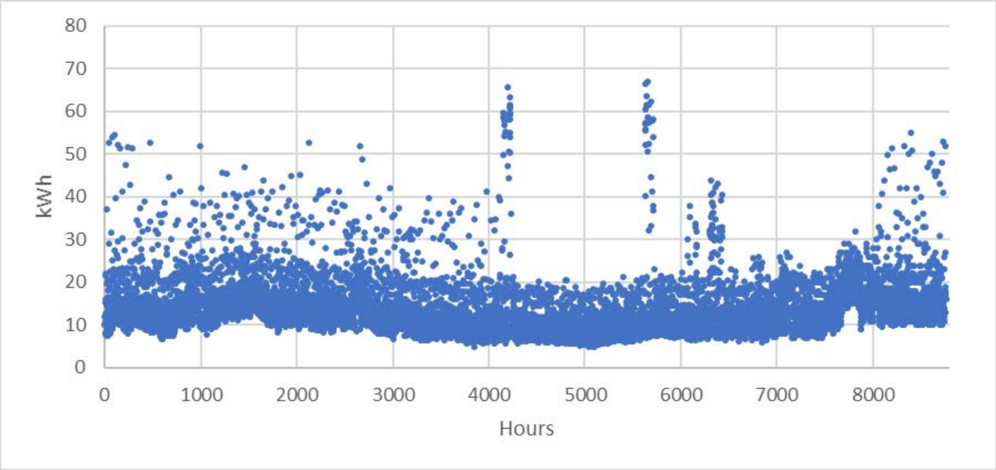

Figure 27. Load profile Demo 4 Rye: hourly loads (2017)

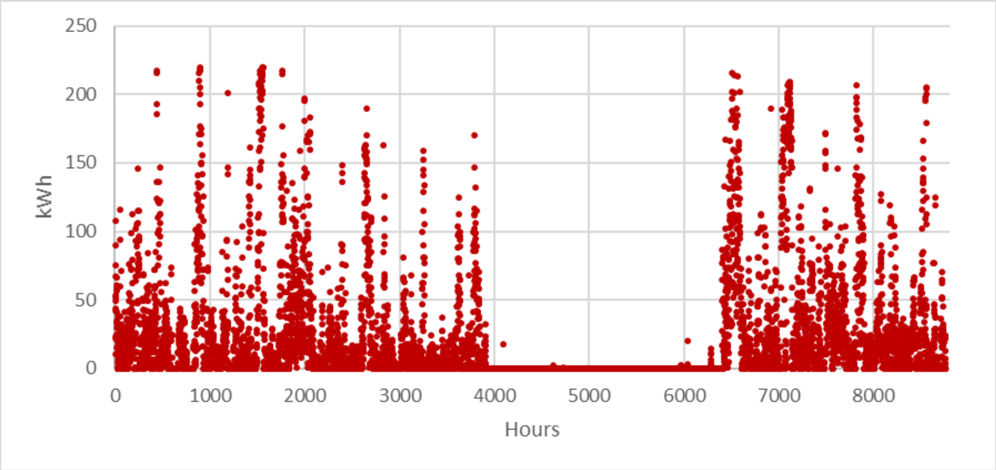

Figure 28. Supply profile Demo 4 Rye: hourly supply (2017)

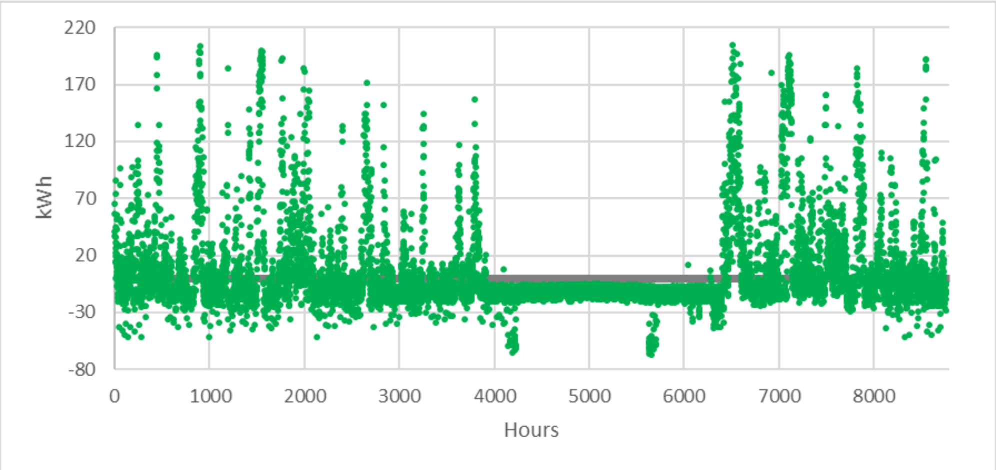

Figure 29. Discrepancy supply - load Demo 4 Rye: hourly values (2017)

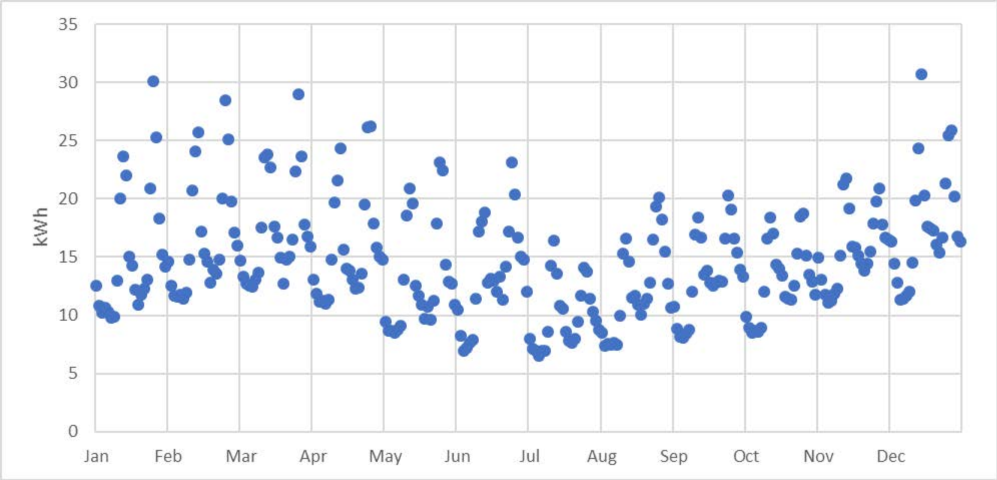

Figure 30. Load profile Demo 4 Rye: hourly loads for an average day per month (2017)

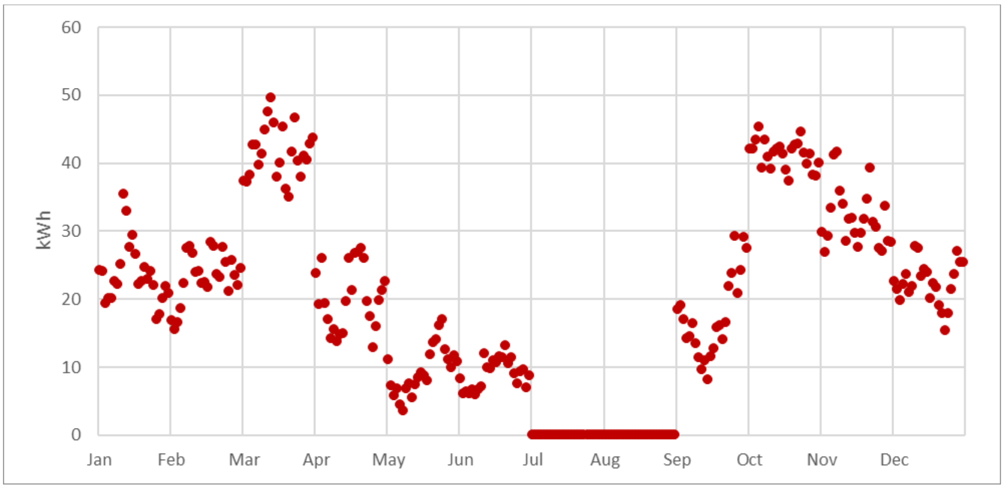

Figure 31. Supply profile Demo 4 Rye: hourly supply for an average day per month (2017)

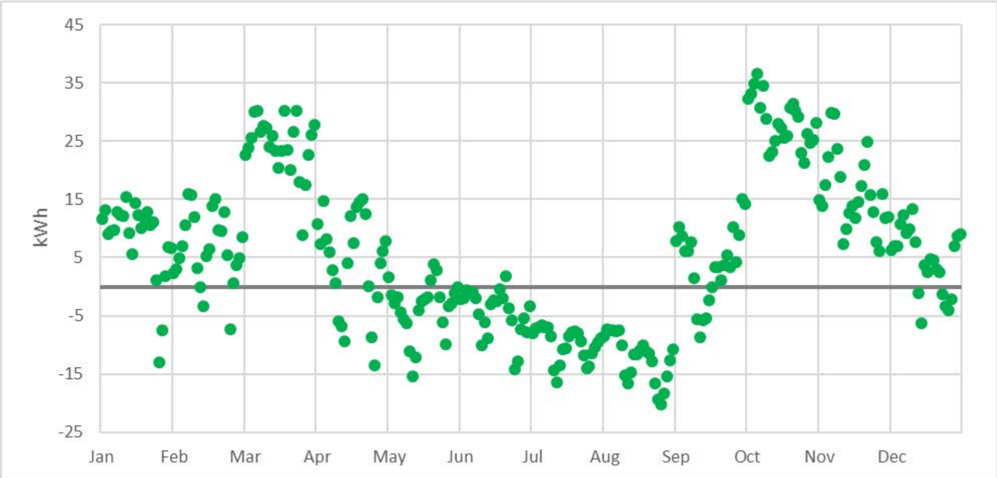

Figure 32. Discrepancy supply - load Demo 4 Rye; hourly values for an average day per month (2017)

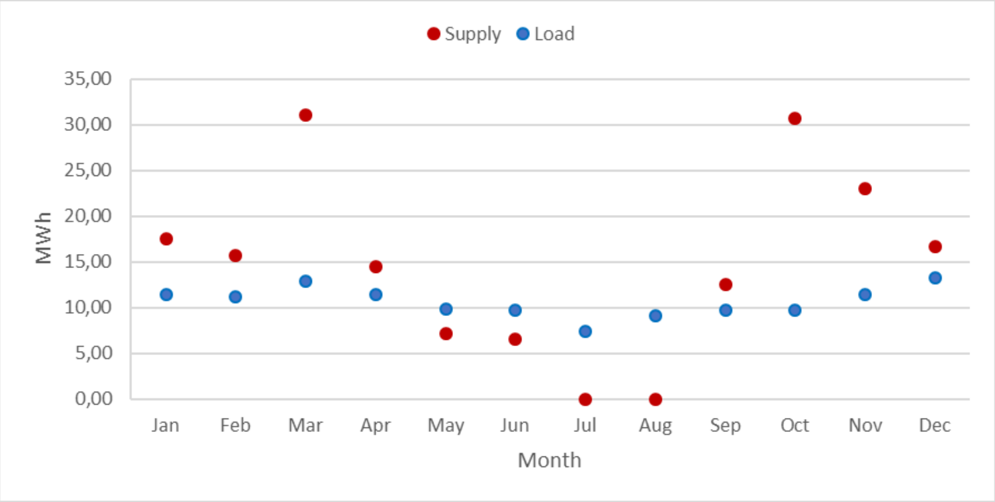

Figure 33. Load and supply profiles Demo 4 Rye: aggregated monthly load and supply (2017)

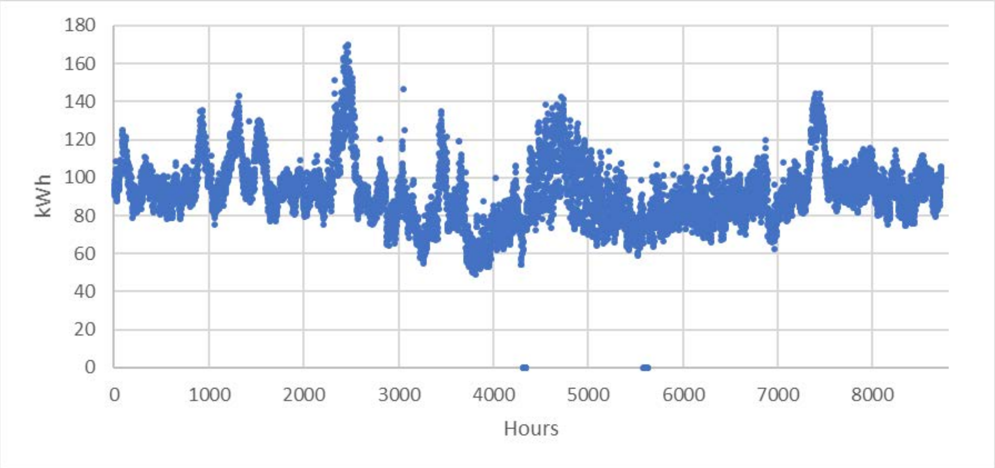

Figure 34. Load profile Demo 4 Froan: hourly loads (2017)

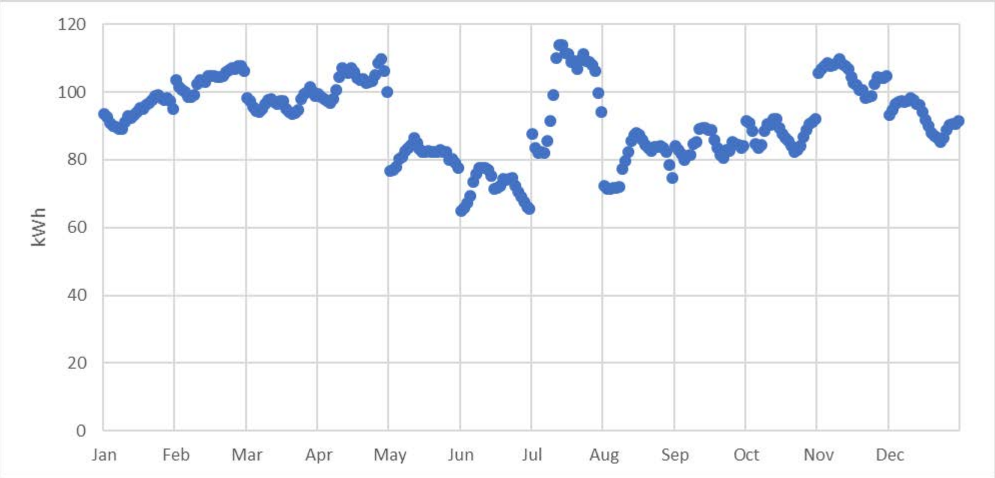

Figure 35. Load profile Demo 4 Froan: hourly loads for an average day per month (2017)