ALP STORE

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EUROPEAN TERRITORIAL COOPERATION
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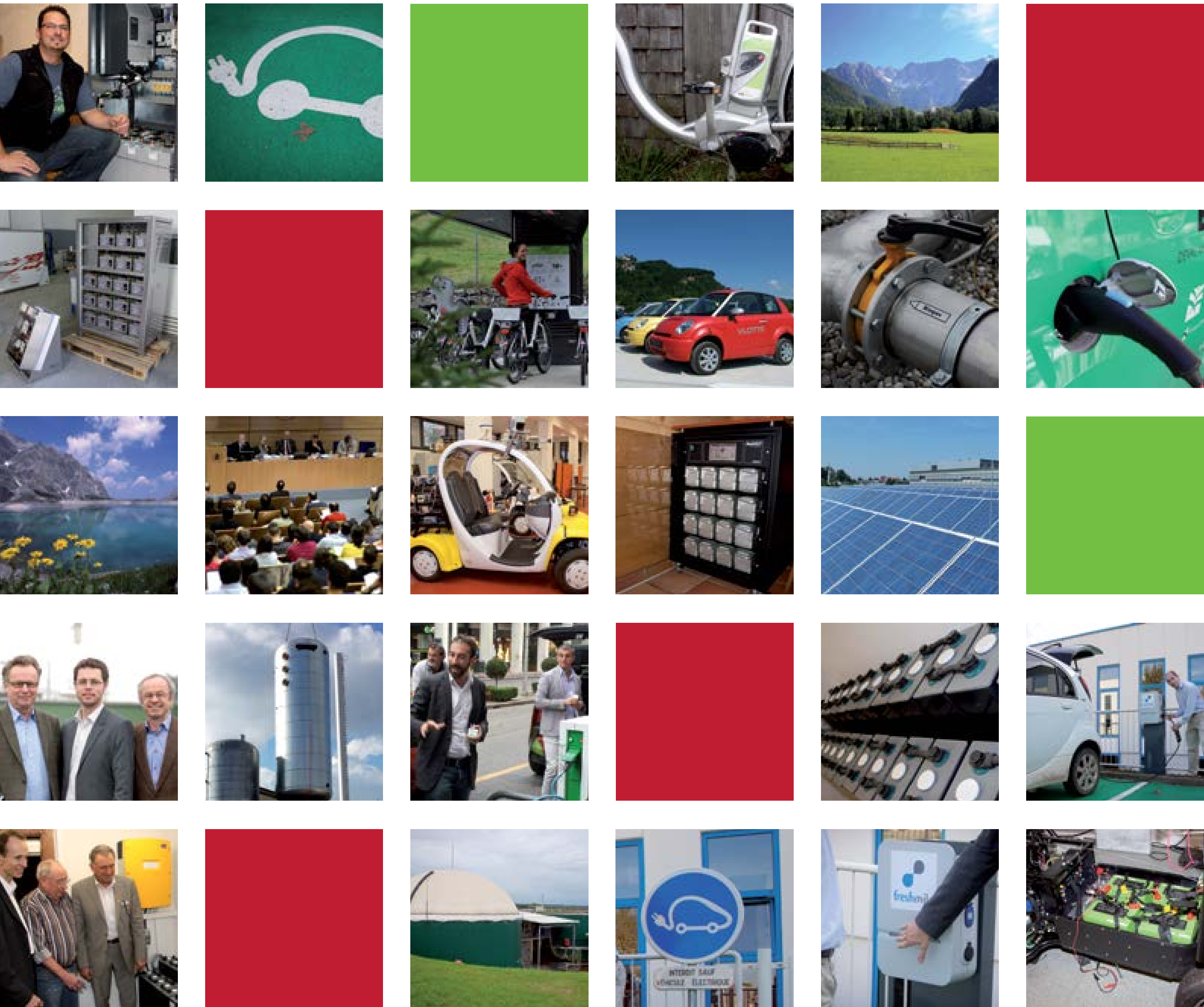
AlpStore project

Case Studies



Imprint

AlpStore Case studies, March 2015

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Project:	**AlpStore** A model to develop and decide upon holistic solutions to increase regional renewable energy supply and outbalance volatility with appropriate buffering means.
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Published by:	B.A.U.M. Consult GmbH, Gotzinger Str. 48, 81371 Munich, Germany www.baumgroup.de
Pictures:	Pictures by Fausto Massi (A.L.O.T. Sc.ar.l) and by the whole partnership
Graphic Layout:	A.L.O.T. S.c.a.r.l., Agency of East Lombardy for Transport and Logistics
Download:	The Case studies can be downloaded from www.alpstore.info

Legal disclaimer:

The work done in the project “**AlpStore**: Strategies to use a variety of mobile and stationary storages to allow for extended accessibility and the integration of renewable energies” (**AlpStore**) and the establishment and update of this publication received funding from the European Territorial Cooperation Programme “Alpine Space” 2007-2013 (European Regional Development Fund), under a subsidy agreement concluded between the Land Salzburg and B.A.U.M. Consult GmbH München / Berlin (Lead partner of the project).

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Table of Contents

Foreword

Prosperity of the Alpine Space depends on the availability of energy. While energy provision can be achieved with local resources such as water, wind and sun, storage is necessary to bridge times of low generation. These guidelines are addressed to planners and practitioners who aim to contribute to the local energy transition by implementing ambitious energy and climate protection plans. The energy turnaround will not work without proper storage technologies. But how many storage facilities do we need, which ones, where and when? And how can local citizens, regional enterprises and tourism equally profit from a renewable energy infrastructure with storage?

In **AlpStore**, 19 partners from all 7 Alpine countries investigated the short, medium and long term requirements for both stationary and mobile energy storages. They tested storages that need to be available all the time as well as others such as the batteries of electric vehicles, which may be disconnected from the power grid for a while. They used a wide range of technologies, such as biogas and hydrogen. They tested second life batteries and developed communication strategies and actively involved local citizens.

This set of 12 case studies shall give an insight in the technologies, their availability and potential use cases. Partners of the local pilot applications share their findings, results and experiences. That shall allow a broad range of practitioners and planners to gain better understanding of how energy storage systems work and how they can help secure the prosperity of the Alpine Space.

As leader of the **AlpStore** partnership, let me express my deepest respect to all our partners. They have been pioneers and they have succeeded in overcoming multiple organizational and technological hurdles.

On behalf of the entire partnership, let me say „thank you“ to all funding institutions on a European, national and regional level. We hope that all followers will have the courage and spirit to include storage options in their energy system and to instigate a long-term change towards an energy system that incorporates an increasing amount of renewable energy.

Ludwig Karg, Executive Director of Lead Partner B.A.U.M.

Introduction

1 Energy storage for the Alpine Space

1.1 Challenges and Constraints

Prosperity of the Alpine Space depends on the availability of energies. Fortunately enough, Alpine countries are predestined for multifaceted decentralised generation of power from renewable energy sources (RES). Many of those are intermittent and matching generation and consumption is quite a task. While controlling the generation may cause negative economic effects and consumption management offers limited potential, intelligent storage technologies can provide for cost effective buffering in metropolitan as well as scattered habitats. In its Energy Roadmap 2050, the EC claims that "storage technologies remain critical" and refers to "batteries, fuel cells and hydrogen, which together with smart grids can multiply the benefits of electromobility both for decarbonisation of transport and development of RES". The EC calls the Smart Grid "a fully integrated network-planning for ... distribution, storage and electricity highways" and calls for innovative instruments to finance the necessary investment - including Public Private Partnerships.

While the extension of pumped hydro storages meets natural and societal barriers, other technologies can bring added value to homes, towns and regions. However, there is a lot of uncertainty with decision makers as to the viability of small, medium and large-scale storages. With explorative and piloting actions, **AlpStore** partners assessed, which mixture of technologies will best fit to the Alpine Space needs. They assessed storage and mobility concepts in regional and municipal planning and investigated needs and potentials to integrate these important areas of regional activity.

1.2 Opportunities and Benefits

Energy storage is not an end in itself, but a means to an end. Besides intelligent grids, storage systems will be key enablers for a future mostly renewable energy supply. The ultimate objective of energy storage is to help meeting human needs such as lighting, motion, heating, cooling, transport, information, products, etc. For that purpose, energy is required and depending on how these needs are addressed, the required form of energy might be electricity. As these needs are fundamental, the provision of energy must be secure, reliable, and affordable, but also non-detrimental to the climate and ecologically friendly. A broad consensus exists that an energy supply system that fulfils these criteria must be mainly based on Renewable Energy Sources (RES) on a worldwide scale at last by the middle of the 21st century. Sun, water and biomass are a natural capital of the Alpine Space. It is necessary to use them for the production of energy. An analysis of the potentials of different RES shows that a suitable mix of renewable energies will be dominated by electricity generating technologies making use of the intermittent sources of solar radiation and wind power. At this point storage comes into play on a larger scale than ever before.

1.3 The AlpStore Project

The **AlpStore** project concentrated on the Alpine specific challenges and opportunities related to energy storage. Partners in seven countries investigated the short, medium and long-term requirements for storage. They created regional master plans for the deployment of both stationary and mobile technologies. Pilot implementations in all participating regions have shown the feasibility of storage in public infrastructure, business parks, enterprises and smart homes. From there the STORM concept and guidelines for decision makers, planners and practitioners (available from the **AlpStore** website www.alpstore.info) have been derived.

AlpStore Project Partners	
B.A.U.M. Consult GmbH (Lead Partner)	Germany
A.L.O.T. s.c.a r.l. - Agency of East Lombardy for Transport and Logistics	Italy
AGIRE Local Energy Agency of the province of Mantova	Italy
Autonomous Region of Valle d'Aosta	Italy
Euroimpresa Legnano s.c.r.l.	Italy
Voralberger Elektroautomobil Planungs- und Beratungs GmbH	Austria
European Centre for Renewable Energy	Austria
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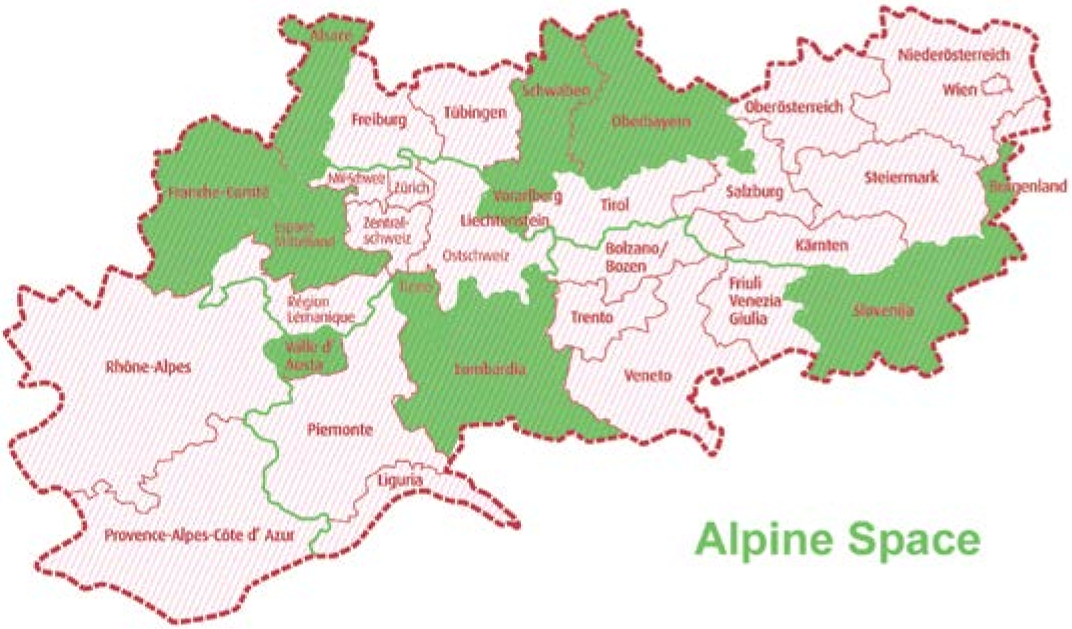


source: B.A.U.M., 2013

Fig. 1 AlpStore activities spread over the entire Alpine Space

The **AlpStore** activities have been focussing on the following objectives:

- Using storage and electric vehicles in the energy provision system will become a key for ensuring stable energy supply in all Alpine regions. With reliable energy provision, regions stay attractive as living habitats, working spaces and recreational sites. The consortium partners investigated latest technology, assessed the potentials and deployed it in pilot cases.

The results of these pilot implementations are described in the Case Studies document you are reading.

- The transnational **AlpStore** team developed the STORM-concept. It stands for "*Smart Storage and Mobility*" and describes a model to develop and decide upon holistic solutions to increase regional RES supply and outbalance volatility with appropriate buffering means.
- Requirements of scattered habitats have been emphasized as well as combined business and living habitats in metropolitan areas. With intelligent storages, both can become self-contained energetic cells on the grid. New power systems integrating mobility and energy supply enable the establishment of entrepreneurial collectives managing such local generation, storage and consumption cells.
- **AlpStore** has shown how electric mobility brings improvements for the Alpine Space connectivity and new business opportunities. Integrating mobility into the energy system can close the cost gap of electric mobility. To assess these opportunities **AlpStore** compared battery EVs with gas and hydrogen solutions.
- Twelve test site implementations with a variety of stakeholders and Alpine Space technology companies provided reliable input to sensitise political and business decision makers for new opportunities in the combined field of mobility and energy provision. Visiting tours and experience exchange workshops have been offered. Big conferences in Italy and Germany attracted more than 500 participants.

1.4 The STORM Concept

STORM stands for "*Smart Storage and Mobility*". It is a model to develop and decide upon holistic solutions to increase regional RES supply and outbalance volatility with appropriate buffering means including mobile storage.

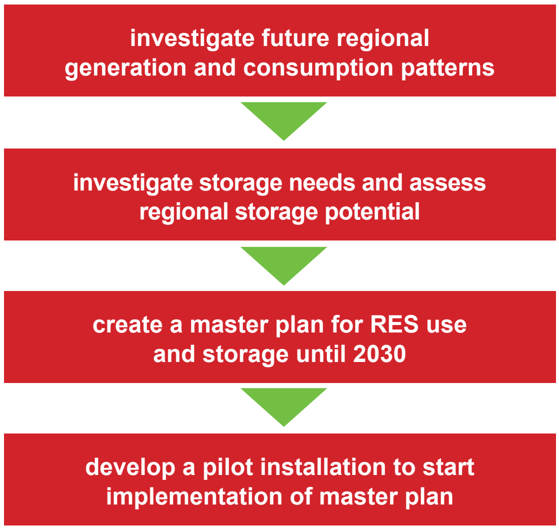
The general STORM workflow comprises four steps:

1. Investigation of future regional generation and consumption patterns

This task will normally have been accomplished by developing a Strategic Energy Action Plan (SEAP) or similar regional energy plan.

Such a plan describes the potentials of reducing energy consumption and providing the rest from regional sources as possible.

It should be an integral part of a regional energy plan to describe not only the technical potentials, but also the willingness of the stakeholders and the financial potentials of a region to implement such an energy plan. To that end, the energy plan should describe the needs and objectives of as many interest groups as possible.



source: B.A.U.M., 2014

Fig. 2 The STORM step-by-step approach to a holistic regional energy transition

2. Investigation of storage needs and assessment of regional potential

The more ambitious a region will be to achieve self-supply, the more likely it will need a comprehensive storage plan. While with low penetration of grids with fluctuating generation (below 40 %) in most cases means of generation and demand side control will suffice to maintain stability of the system, with higher penetration the need for storage will quickly increase.

As described in the AlpStore Whitebook and the guidelines for decision makers and practicioners, there is quite a choice of storage technologies with a big variety of characteristics. Some of those highly depend on local givens to be used (e.g. hydro pump stations or large biogas tanks). So it is not only necessary to assess the needs for storage, but also the potentials of local implementation of such systems. As this is true for the generation systems, there may be quite a difference between the technical and economical storage potentials and the real potentials. The latter depend on questions of acceptance and the will to use the chances.

3. Development of a master plan for the renewable energy use and storage until 2030

Having carefully assessed the generation and consumption patterns, a regional storage master plan can be derived. Using the technological and financial hints from AlpStore experts, the storage master plan shall describe:

- Overview of the status quo of the existing regional energy system;
- Overview of the status quo of the envisioned future energy system (typically derived from a SEAP) and describing regional energy generation and consumption as well as the future energy related grids (power, gas, mobility);

- Future Energy Storage Requirements (possibly for 2020, 2025, 2030);
- Potentials for regional Storage including potentials of mobile storage (gas, H2 and electric vehicles);
- National and regional framework for future storage systems;
- Visions and goals of the regional community;
- Roadmap to establish the regional storage farm describing various scenarios;
- Concrete measures and projects for the next few years.

All regions involved in AlpStore have developed such Storage Master Plans (StoMP).

4. Implementation of the master plan by pilot installations

While the StoMP is a long term strategic plan, practically the region needs an implementation plan at least for the first steps. Such implementation plans cover specific projects and describe the pilot installation process in detail.

It is a question of motivation and "time to market" to not wait with practical steps until everything is ready in the plan. Therefore, ***AlpStore*** *proposes to implement "no regret measures" during the development phase (see the AlpStore guidelines for a list of such measures).*

More detailed information about the STORM concept, including recommendations for local and regional authorities, regional energy utilities and investors, can be found in the **AlpStore** White Book as well as in the "**AlpStore** Guidelines for Decision Makers" and "**AlpStore** Guidelines for Planners and Practitioners". They are available from the **AlpStore** website (www.alpstore.info).

Alsace, France
Alsace Auto 2.0
Case study

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Case studies are contributing to AlpStore WP6
Work Package 6 Responsible: EUROIMPRESA LEGNANO s.c. a r.l.
Lead Partner: B.A.U.M. Consult, Ludwig Karg, Patrick Ansbacher, Anja Lehmann

1 Storage technologies for the region Alsace - general frame conditions and objectives

There is a long-term trend towards an increased share of renewable of energy sources in the national energy mix. This goal has been serveral times restated by the current government. A word has been coined, the “transition énergétique”, very similar to the German concept of “Energiewende”. A new important law is currently in preparation by the Ministry for Environment, it is the “loi de transition énergétique”. Last but not least, Paris will host the COP21 conference in October 2015 and the President had promised to shut down at least one nuclear power plant – though it is more a symbol than a real industrial decision.

The necessary development of renewable energy is the main driver between the promotion of energy storage in France. Nowadays the national focus is on the development of competitive technologies and the study of relevant economic models. Demonstration project are used to assess the performances of different energy storage solutions.

Referring to sustainable mobility the successive French governments have made the development electric or hybrid vehicles a high priority in their policies to reduce greenhouse gas emissions. The national plan originally aimed for 2 million electric cars or hybrid on the road by 2020. Even if the market share of EVs and PHEVs is clearly improving, the consensus is that this target will be missed.

The government is financially supporting the deployment of a recharging infrastructure for EVs through the commitment and the collaboration of local communities, alongside co-financing with government agencies such as ADEME. Recently, the government has launched a large-scale consultation to have operators installing up to 16,000 charging points over the country. The large family-owned conglomerate Bolloré is likely to win the tender, ahead of EDF, the state-owned electricity company.

The Caisse des dépôts is also very active in the field, by financing projects and companies in the field as well by being one of the founders of Gireve, the interoperability platform (quite similar to the Hubject concept in Germany). The Caisse des dépôts is the financial arm of the French government, managing most of the money it invests into the public and private economy.

Electric cars constitute an important brick of any future electrical network, as mobility require sizeable energy needs and potentially high peak-hour power demand. An electric car being essentially a large battery on wheels, once connected to the grid, it can be considered as a means of storage. Any large pool of cars connected to the grid can be considered as distributed energy storage.

The integration of any storage means necessitates an adapted electrical grid, a so-called smart grid. Today, the main activity in the smart grid sector is represented by the fostering of the capacity market after the ratification of specific regulation on certification schemes for load management with the aim to raise the value of load management and demand response. A national smart grid strategic road map does not really exist as such. The initiative mainly remains with local projects carried out in cities, such as in Nice or in Issy-les-Moulineaux.

Regarding the level at which decisions are made, France is divided into administrative regions. The regions are further subdivided into departments and so on until the smallest administrative entity of municipalities. There is a currently a reform ongoing to reorganise territories and competencies. However, at this stage, it is too early to assess how this will impact the implementation of energy policies.

The trend seems to go towards a less centralized organisation, this being backed by the “loi de transition énergétique”, which should allow more initiative at local level regarding the control of the local distribution grid by elected bodies.

So far, the grid was managed by decisions made in Paris, either in the ministries or within EDF, the state-owned electricity company, which enjoys a near-monopoly in France, with a de facto control over 95% of the distribution grid. Cities, departments and regions had little say in the evolution of their grid. Even though the grid technically belongs to the local entities, in most of the cases it has been awarded in long-term concessions to ERDF, the EDF subsidiary in charge of managing distribution grids.

In Alsace, the situation is slightly different, as there is a local electricity company (Electricité de Strasbourg), which now operates the distribution grid, supplies electricity to households and large clients and also supplies natural gas. However, ES is fully-owned by EDF.

As a consequence, in Alsace as in most other regions in France, there is no local energy policy, de facto nor de jure. This means that there is no specific framework for energy storage, beyond isolated demonstration projects, such as Alsace Auto 2.0.

1.1 Actual and future regional energy system

Alsace consists of two departments: Bas-Rhin in the North and Haut-Rhin in the South. As mentioned above, the dominant energy player in Bas-Rhin is Electricité de Strasbourg, with a 95% market share on its territory, which comprises Strasbourg and most cities in the department. In the South, EDF is the dominant player, with the exception of the city of St Louis, where EBM, a Swiss utility, is the main player. There are also a handful of local mini-utilities.

Freshmile has got statistics on the Bas-Rhin (ES area), where baseload electricity consumption amounts to 600-700 MW and peak-load can climb up to 1,000-1,200 MW in peak hours during the coldest winter days (a very rare event).

There is local power production capacity with hydro power plants on the Rhine river shared with Germany. There is also one nuclear power plant in Fessenheim. However, the region is interconnected and draws its energy from the European grid.

The distribution grid is very strong in the Strasboug area. It may be weaker in some areas in the Vosges mountains, most notably in the South. Note that Freshmile is not a utility and does not have access to detailed information about the state of the grid nor the state or uptime statistics of the power plants.

Regarding energy storage, there is no significant system in place beyond a handful of small demonstration projects. Electricity storage in particular is today not a constitutive element of the electrical system in the Alsace region.

To the best of our knowledge, there are no formal plans for the future. We can expect the “loi de transition énergétique” to set certain goals that will call for energy storage in the medium to long term. We do not expect any evolution for energy storage in the short term.

1.2 Regulatory framework

The laws and regulations in France do not contain specific provisions for energy storage devices. Such devices are now apprehended by their action on the networks.

Thus, any entity storing electricity must pay the fee applicable to consumers using electricity when the electricity is withdrawn from the network to charge the storage device and pay the fee applicable to producers when the storage device injects electricity to the public electricity grid. This mechanism is the one which is today applied to energy transfer stations by pumping (STEP) which are, in terms of their use of public electricity network, in a comparable situation.

The proposed new directive on energy efficiency resulting from a compromise between the Council of the European Union and the European Parliament, was formalized in September 2012. This draft Directive explicitly mentions the storage of electricity and provides that national regulators should ensure that network tariffs do not prevent network operators and suppliers to offer energy efficiency services as displacement of the peak consumption to off-peak periods, the load shedding mechanisms, the development of distributed generation or energy storage.

The capacity market under the NOME law could include an obligation for the storage of electricity. Works for the definition of this market are currently ongoing under the auspices of the Réseau de Transport d'Electricité in consultation with all actors electrical industry.

As mentioned above, the new "loi de transition énergétique" currently in preparation may have an impact over the rules and economics of energy storage, and broadly speaking over the large-scale integration of renewable energy sources into the grid.

2 Pilot project Alsace Auto 2.0

Alsace Auto 2.0 aims at managing the charging process of electric vehicles (EV) in order to aggregate the batteries into a fleet that can be considered as a decentralised virtual power plant. It is a mobile energy storage solution.

At commercial scale, the activity will be of Freshmile acting as a mobility operator and load aggregator, managing the charging process of the fleet of EVs under management, thanks to realtime bidirectional communication with charging stations and cooperation with utilities and energy providers to monetize the buffer hence created by the batteries. End-users will pay a price plan for the service, leading to the development of a business model and billing system based on the charging service provided, and no longer on the number of kWh sold, as read by the meter.

Before commercial activities are launched in 2015, the pilot project Alsace Auto 2.0 aims at demonstrating the technical feasibility of the solution proposed, as well as the acceptance by end users. Freshmile develops both the business model and the software part of the solution. Hardware (charging equipment) is sourced from Hager, a French-German major electrical equipment manufacturer in Europe.

The pilot project originally consisted of 25 EVs and their charging stations. Because of a lack of financing, the project was scaled down to 3 EVs in 3 demonstration sites.

2.1 Characteristics of the field test

The main pilot site is located Freshmile's office, located on the Strasbourg airport platform, in Entzheim, near Strasbourg. One charging station is installed and remote-controlled to charge Freshmile's company car, a Peugeot iOn electric vehicle.

The second pilot site is located in Sélestat, a city located ca. 50 km south of Strasbourg. In this site, the charging station is installed in a passive house, equipped with a photovoltaic roof to produce electricity.

The third pilot site is installed in Pfaffenhoffen, a small town located ca. 20 km north of Strasbourg, in an open space, with the charging station in open access.

The first pilot site was chosen for the main reason that it is located in Freshmile's office, making it convenient for tests and trials. Another reason is that Freshmile offices are located at the Strasbourg airport, which is within the boundaries of a former military air force base. Being an air force base, the site was not administered by the usual utilities, be it for telecoms, gas supply and electricity supply. As a result, still today, the electricity distribution network and the electricity supply within the airport boundaries are managed directly by the local airport management company. For Freshmile, it is a very convenient setting, as there are no regulatory restrictions to submeter electricity and to differentiate uses and bills at the meter. Freshmile has agreed with the airport that the electricity for the EV is metered and billed separately. Such an arrangement would have been impossible in an office building or in a house where the electricity is supplied by one of the conventional utilities, such as Electricité de Strasbourg or EDF.

Picture of the first site in Entzheim, with a 22-kW charging station and two dedicated parking spots

With Freshmile office building in the background

The second site was chosen after meeting several times the property developer, Maisons Hanau, who is a local construction company with a keen interest in promoting the idea that passive houses coupled with EVs and smart charging is the key to environment-neutral individual houses. In fact, construction land is becoming rare and expensive, leading families to build houses far away from town centres and business parks. Hence, the environmental footprint of a family leaving in such a house is very high: arable land converted into concrete, high heating needs for detached houses, two cars in most cases and several dozens of kilometres driven per day. But with decentralized power such as photovoltaic and smart charging of at least one electric vehicle, the environmental footprint can be minimized. Since then, this installation as won a prize for energy transition, awarded by Idée Alsace, an industry association.

Picture taken on the inauguration day, with the 7-kW charging station on the wall

The third site was also developed with Maisons Hanau. The difference with the second site is the charging station is in open access, on one of the main access roads to the city.

Picture of the Pfaffenhoffen site during construction, with the charging station in open access on the left-hand side of the house, under the window

Compared to the original project, the pilot project Alsace Auto 2.0 was hence scaled down from 25-50 vehicles and charting sites to 3. As explained above, this decision was made primarily because of a lack of available financing to purchase and install the vehicles and the charging stations. However, the IT infrastructure, the algorithms and the mobile applications have not been scaled down in their scope, meaning that the solution developed by Freshmile for Alsace Auto 2.0 can handle 3, 30, 300 or 3,000 users without any difference. In fact, the technology developed within the project is now the backbone of the "Freshmile Charge" service, that Freshmile has been successfully marketing since Q4-2014.

The technical solution chosen for the pilot sites can be described as follows:

- Charging stations manufactured by Hager, either 1-phase or 3-phase, depending on the available power on site (22 kW in Entzheim, 7 kW in Sélestat and Pfaffenhoffen)
- OCPP communication protocol between charging stations and Freshmile's servers
- Data connectivity over Ethernet, with direct connection to the Internet box
- 1 x Type 3 socket on each charging station
- 1 x EF (domestic) plug on each charging station, for slow charge
- ID reader compatible with most RFID and NFC devices
- Conventional access control with a dedicated RFID card
- Innovative access control with any compatible card
- Monitoring software provided over the web as software-as-a-service
- Mobile monitoring software, including charging process control over the smartphone

Freshmile enjoyed much support from local partners and stakeholders: Maisons Hanau, Hager, Caisse des dépôts, Communauté urbaine de Strasbourg (now Eurométropole Strasbourg), Région Alsace, Pôle véhicule du futur, Pôle Energivie, Alsace Innovation and the Banque Publique d'Investissement.

Maisons Hanau's role was instrumental in making the second site a reality. The coupling with such a negative-energy house makes perfect sense, hence the prize awarded to this demonstration site. Maisons Hanau is a private company.

Hager is also a private company, albeit a large one, with EUR 1.6 bn turnover and over 12,000 employees in the world. Hager is a leading electrical equipment manufacturer in Europe, with over 30% market share in France on residential and small building electrical installations. Hager is headquartered in Obernai, 15 km far away from Freshmile's offices, allowing for close cooperation. Hager supplied the charging stations used in the demonstration sites. Since then, Hager and Freshmile have won several tenders to commercialise charging stations equipped with the "Freshmile Charge" service.

The **Caisse des dépôts** has supported the Alsace Auto 2.0 project since the beginning, allowing the scheme to be financially supported by the Plan Investissements d'Avenir, the French government stimulus package launched in 2009 to boost innovation and growth. The Caisse des dépôts is represented in Strasbourg by its "direction régionale".

The **Eurométropole Strasbourg** is Freshmile's territorial partner in Alsace Auto 2.0, as Entzheim belongs to the Eurométropole Strasbourg. Expansion plans for Freshmile services are currently in discussion.

The **Région Alsace** has also supported the Alsace Auto 2.0 since the beginning. It was the local public co-funding to the Feder tranche. Expansion plans for Freshmile services are currently in discussion with the Région Alsace. Besides, the Région Alsace also supports an innovative project by Freshmile around collection of mobility data through smartphones.

The **pôle Véhicule du Futur** has "labellized" the project, as well as the **pôle Energivie**. The pôles are industrial clusters. The first one relates to the automotive industry and mobility services. The second ones relates to smart home, smart building and energy networks.

Alsace innovation is the Région Alsace's innovation agency. It has been supporting Freshmile in helping identifying new markets and opportunities as well as assisting the company in preparing applications for European projects and grants.

Last but not least, the **Banque Publique d'Investissement** provided Freshmile with grants at the very beginning and more recently with loans to finance to its working capital needs.

At this stage, it is too early to say what impact the Alsace Auto 2.0 pilot project could have for the energy future of the region. Simulation results shown in the next sections may give a hint of how mass-market electric mobility could affect the grid and create room for innovative energy services.

2.2 Storage technologies and frame conditions

Alsace Auto 2.0 relies on distributed electrical storage provided by batteries inside electric vehicles. The technology used is Lithium-ion. It will remain Lithium-ion in the foreseeable future, for pure electric vehicles as well as for plugin hybrids. Economies of scale and technical improvement allow for optimism about the room for improvement that is still available. 2nd generation cars in 2017-2018 will offer twice as much range than the 1st generation cars currently on the roads. This should lead to an increase in the market share of electrified vehicles, hence creating the conditions for charge management and energy storage management through fleet of distributed "batteries on wheels".

Studies led by EDF show that in terms of energy, the challenge of charging electric vehicles and plugin hybrids (EV and PHEV) on the electrical distribution network represents at a horizon of 10 years, from 1 to 3% of the energy distributed in low voltage (LV) in France today. This energy will be added to the amount of energy already withdrawn from networks and modify accordingly the impact on the national load curve.

Incentives for recharging during low demand periods will be necessary to smooth this new demand. Initially, optimization of charging periods could take account of the production of renewable energy sources. In a second stage, smart grids technologies could be considered to discharge some electric vehicles in order support the electrical system (diffuse support ...). It is widely discussed under the concept of vehicle-to-grid (V2G). For a fleet of one million electric cars connected to the grid (electric vehicles plan of the French government forecasts a total of 2 million EVs by 2020), the storage capacity could reach 10 GWh. This storage capacity could be valuable at peak but it assumes that consumers have adopted the VE and good behavior when it comes to charging their vehicles.

Freshmile is currently discussing with a number of regional electricity providers interested in using the distributed energy storage capacity of electric cars to level their charging curve and source cheaper electricity for their needs on the wholesale markets.

2.3 Research design and schedule

The implementation plan was formulated in 2013 as follows:

1/ Hardware

a/ Install charging stations in 3 or more pilot sites

b/ Set up a submeter to identify the electricity used to charge the electric vehicle c/ Set up a communication link such as Ethernet, wi-fi or a sim card to allow remote-controlled charging process

d/ Set up configuration files in the charging station to allow it to communicate with Freshmile servers over the OCPP 1.5 protocol

2/ IT infrastructure

a/ Set up a server to centralize communication messages with the charging stations

b/ Set up a server to collect mobility data (see below mobile app) from users

c/ Set up "Long Jing", the heart of the IT system, that manages the various algorithms, from analyzing user behaviour (see below algorithms) to sending charging messages to the charging stations

3/ Mobile app

a/ Develop a mobile application on Android platform to collect trips from users, in order to analyse their behaviour and predict how they can use an EV, where and when they can charge the EV, where charging stations should be installed to match their needs

b/ Develop the iOS version of the app, for use on iPhone and iPad

c/ Develop a https secured platform to give users access to the mobility data collected by the mobile app

d/ Collect data from 25 to 50 voluntary users, with or without an electric vehicle

4/ Algorithms

a/ Develop algorithms to filter data collected by the mobile app

b/ Develop algorithms to interpret the daily movements of users

c/ Develop algorithms to suggest locations for charging stations, based on users needs

d/ Develop algorithms to simulate the use of an EV, including charging times and energy used

e/ Develop algorithms to simulate charging plans, state of charge and available range, for each hour of the day

f/ Develop basic reporting for users, if possible with data visualisation tools

5/ Impact assessment

a/ Simulate a fleet of EVs in Alsace, on the basis of user data collected

b/ Simulate the charging process of such a fleet

c/ Demonstrate environmental benefits, based on positive externalities linked to the replacement of conventional cars by electric vehicles and to smart charging managed by Freshmile

d/ Demonstrate the local energy storage capacities of such as fleet of EVs acting as a mobile storage

The expected results had been summarized as follows:

1/ Hardware

Output 1: to demonstrate the technical feasibility of remote controlling a number of charging stations

Output 2: to acquire fluency in using the OCPP protocol

Output 3: to develop know-how and procedures to roll out such charging stations on a large scale

2/ IT infrastructure

Output 1: to demonstrate a functioning solution

Output 2: to ensure scalability for large-scale commercial launch

3/ Mobile app

Output 1: to demonstrate a functioning solution

Output 2: to demonstrate the usefulness of such precise collection of mobility data

4/ Algorithms

Output 1: to demonstrate the ability to analyse user mobility habits

Output 2: to demonstrate the ability to scale up

5/ Impact assessment

Output 1: to demonstrate the ability to conduct such a fleet simulation

Output 2: to demonstrate the case for large-scale EV roll-out from an environmental point of view

Although based on a smaller base than originally forecasted, the Alsace Auto 2.0 pilot project is very concrete, in the sense that all IT infrastructure, mobile applications and algorithms are developed without any reduction of scale. Hence this solution could be of use for other partners or for other projects in other countries.

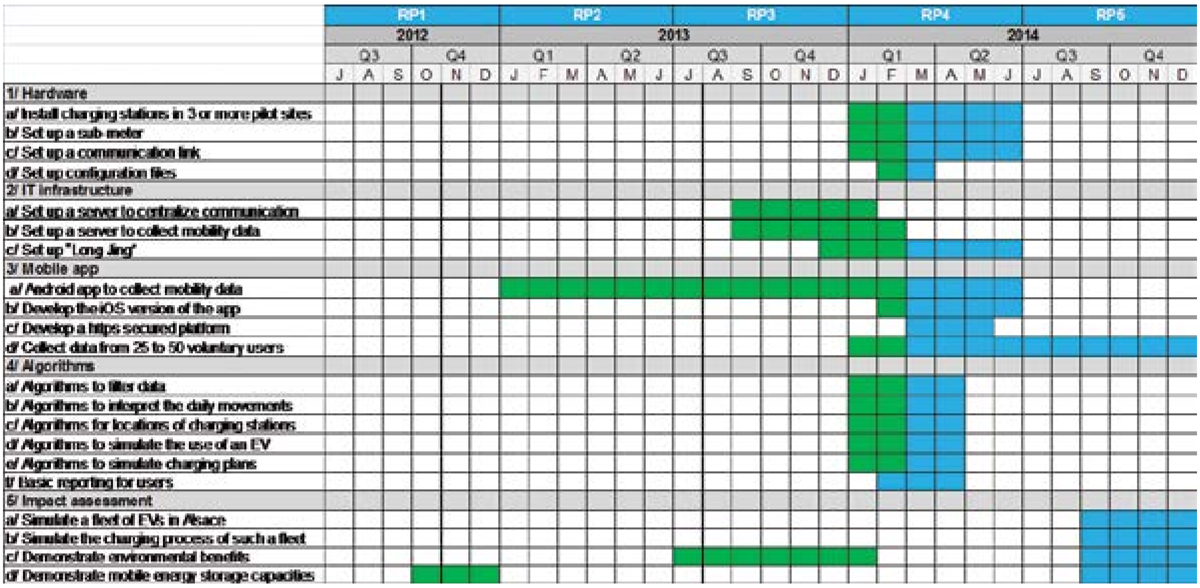
All software is being developed and maintained in English. It is based on existing technology, such as the Python programming language or the OCPP communication protocol. From a technical point of view, here is nothing proprietary or limitative that would prevent the solution from being rolled out abroad. Moreover, the methodology used by Freshmile in the Alsace Auto 2.0 can be replicated in other countries, such as the collection of mobility data, the simulation of user behaviours with an EV and the impact of a fleet of EV over a territory and an electrical grid.

Privacy concerns were addressed at the onset of the project: Freshmile has an agreement to store and process private data from users. This data is physically stored on servers based in Strasbourg, where French law applies. There is no backup or no process whatsoever which is handled abroad, be it inside or outside the EU. Users have access to the record of their data and are given the choice to record their daily trips in an open mode or in a "privacy" mode, which means that trip data is used for statistics and calculations but never appears in their history.

2.4 Implementation process

Milestones were defined.

	Milestones
1/ Hardware	
a/ Install charging stations in 3 or more pilot sites	M1, M2, M3
b/ Set up a sub-meter	M4, M5
c/ Set up a communication link	M6, M7
d/ Set up configuration files	M8, M9
2/ IT infrastructure	
a/ Set up a server to centralize communication	M10
b/ Set up a server to collect mobility data	M11
c/ Set up "Long Jing"	M12, M13
3/ Mobile app	
a/ Android app to collect mobility data	M14, M15, M16, M17
b/ Develop the iOS version of the app	M18, M19
c/ Develop a https secured platform	M20
d/ Collect data from 25 to 50 voluntary users	M21, M22
4/ Algorithms	
a/ Algorithms to filter data	M23, M24
b/ Algorithms to interpret the daily movements	M25, M26
c/ Algorithms for locations of charging stations	M27, M28
d/ Algorithms to simulate the use of an EV	M29, M30
e/ Algorithms to simulate charging plans	M31, M32
f/ Basic reporting for users	M33, M34
5/ Impact assessment	
a/ Simulate a fleet of EVs in Alsace	M35
b/ Simulate the charging process of such a fleet	M36
c/ Demonstrate environmental benefits	M37, M38
d/ Demonstrate mobile energy storage capacities	M39, M40



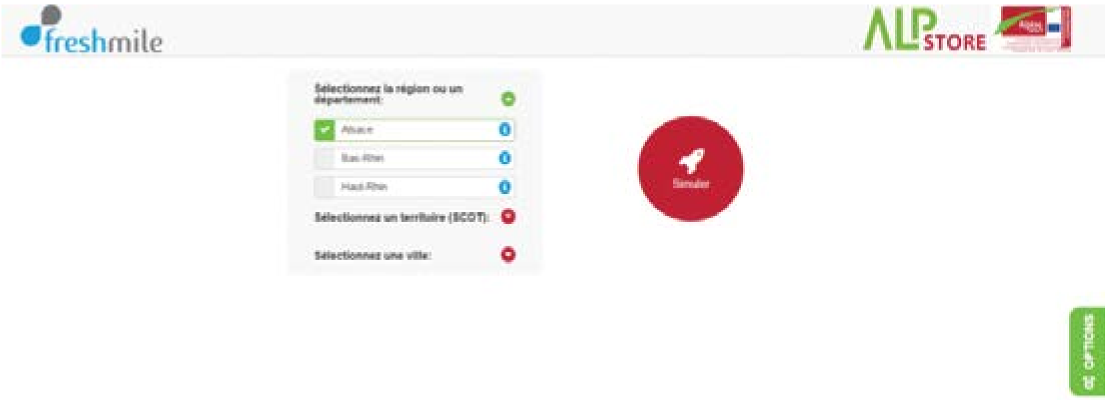
The project started more slowly than expected, mainly for internal organisational reasons at Freshmile, but the team caught up in the course of 2014, with intensive work and results produced during the second half-year.

At the time of writing (at end of December 2014), all milestones were reached and data collection was planned to continue until the end of the project in April 2015 to provide raw material for better algorithms to be developed in the future.

2.5 Scenarios / simulations

Freshmile developed an interactive tool to simulate the impact that a fleet of electric vehicles would have on the electrical grid of a given territory. This tool is freely available online at alp-store.freshmile.com, or through the "lab" page on Freshmile website, at www.freshmile.com/lab.

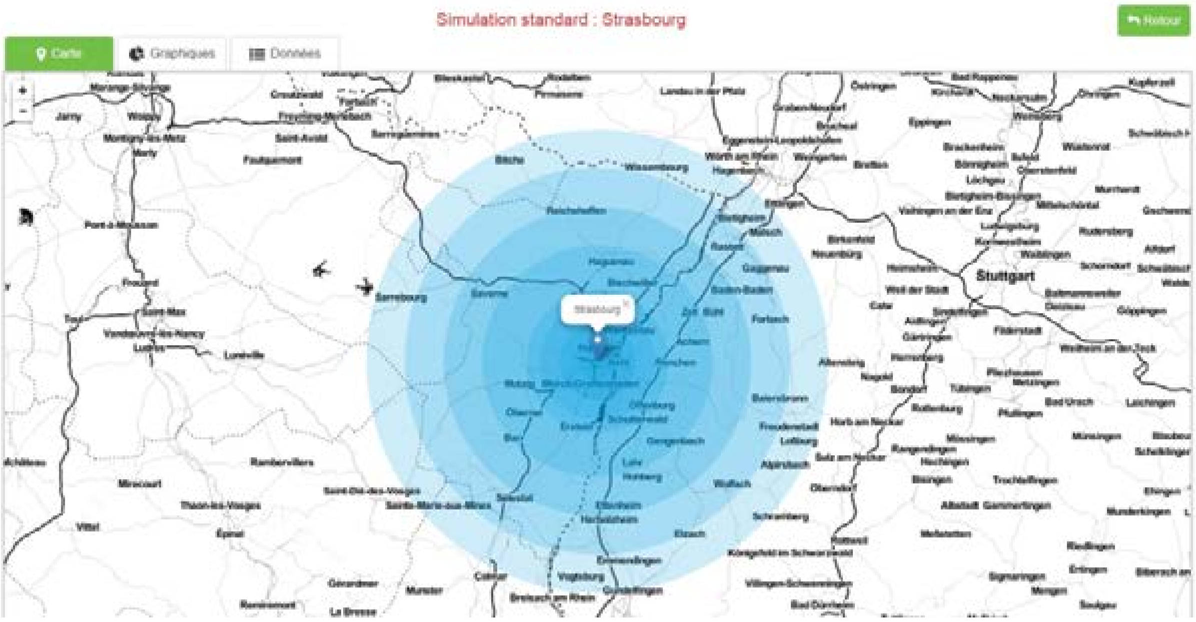
The calculations are based on data collected from the demonstration charging stations, from Freshmile's EV and from the smartphone mobility tracking app.



The main menu launches a simulation on a predefined scenario, with data compiled by Freshmile regarding population, EV market share, working times, energy consumption, rated power of charging stations.

The simulation can be run on different territories, at Alsace level, at "département" level and at smaller administrative and statistics levels (cities and SCOTs).

For instance, the simulation for Strasbourg gives the following results. First “Strasbourg” is selected. The information button on the right shows the population (470,000 inhabitants). The big red button launches the simulation. Then a map appears and shows the simulated driving range for the population, based on the profiles predefined in the standard scenario.



A click on the “graphiques” tab displays two main graphs that describe the impact of electric vehicles for each hour of the day (working days only, not weekends). On the left-hand side, the graph shows the number of EV that would be connected and charging at each hour. On the right-hand side, the graph shows the load demand on the grid, expressed in MW.

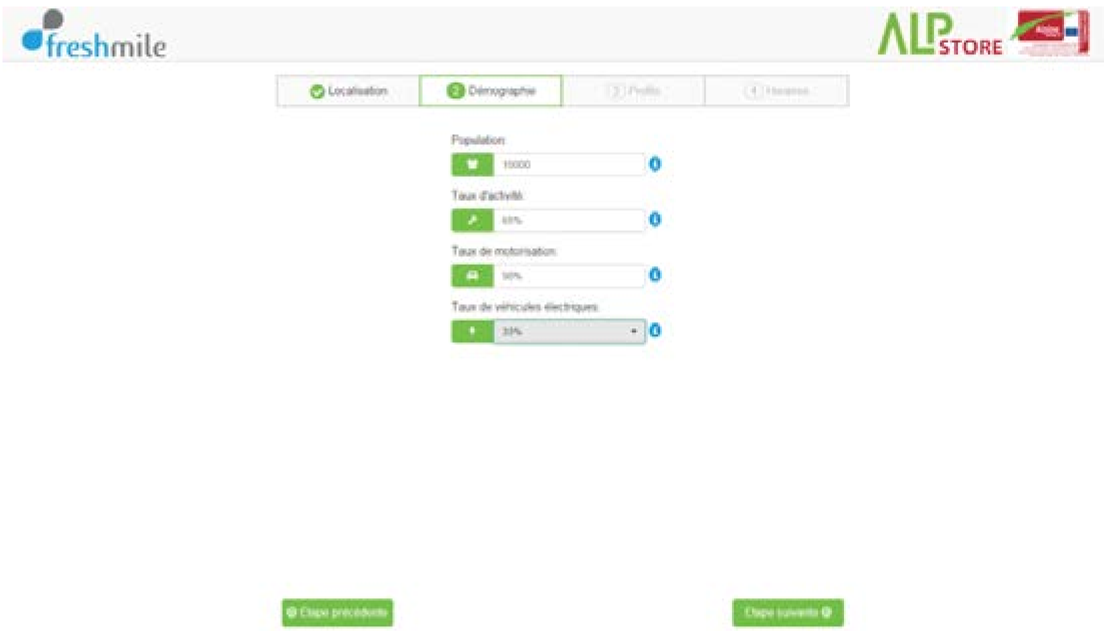
The figures are based on a predefined scenario where electric vehicles have replaced most cars. This is a good hint at how EVs would impact the grid in 15 to 30 years time.

For decision-makers more interested in the short term or for mayors of cities or companies, the “options” panel on the right of the welcome screen provide a simulation tool, where all parameters can be set, as shown below, including the exact location of where to centre the simulation.

Click on “j’essaye” to run the customization tool, which consists of four successive steps. The user first accesses a map, where the center of the simulation can be defined: for instance a city, a district, or the industrial site of company wishing to simulate its fleet of service cars.

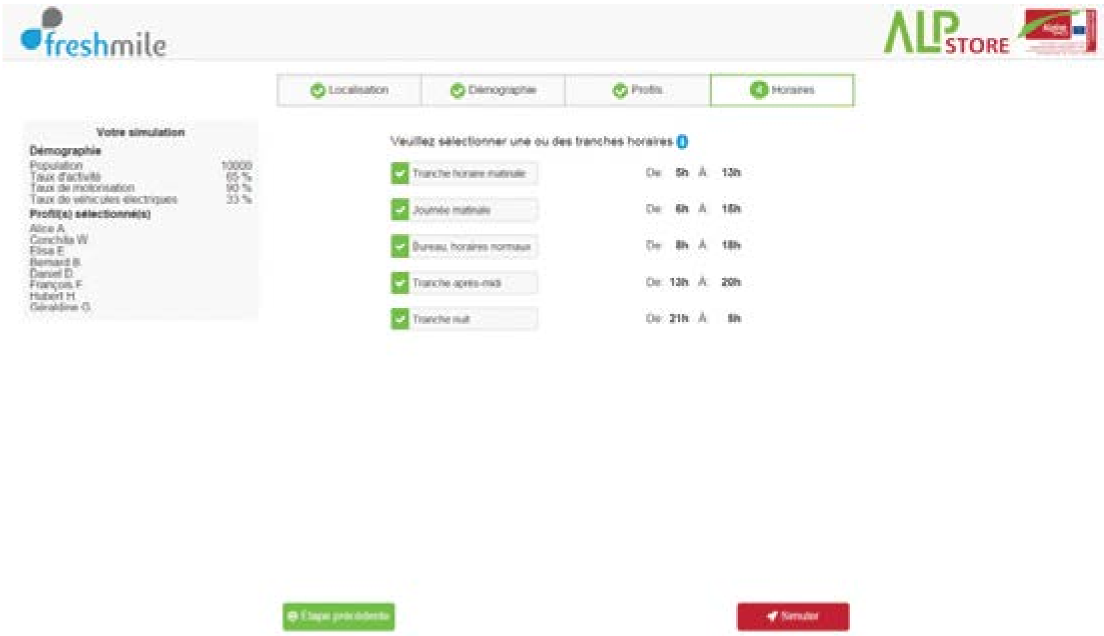
In this case the simulation will be run near the small city of Geispolsheim, in the South of Strasbourg. Then figures are entered for the population, the activity rate (how many people work), the car-ownership rate (how many households do own/lease a car) and the market share of electrified vehicles.

In the following example, the simulation is run for 10,000 inhabitants, 65% activity rate (French average), 90% car-ownership rate (French average outside large cities) and 33% electric vehicles (i.e. roughly most households with 2 cars have switched one of them to electric or plugin hybrid).

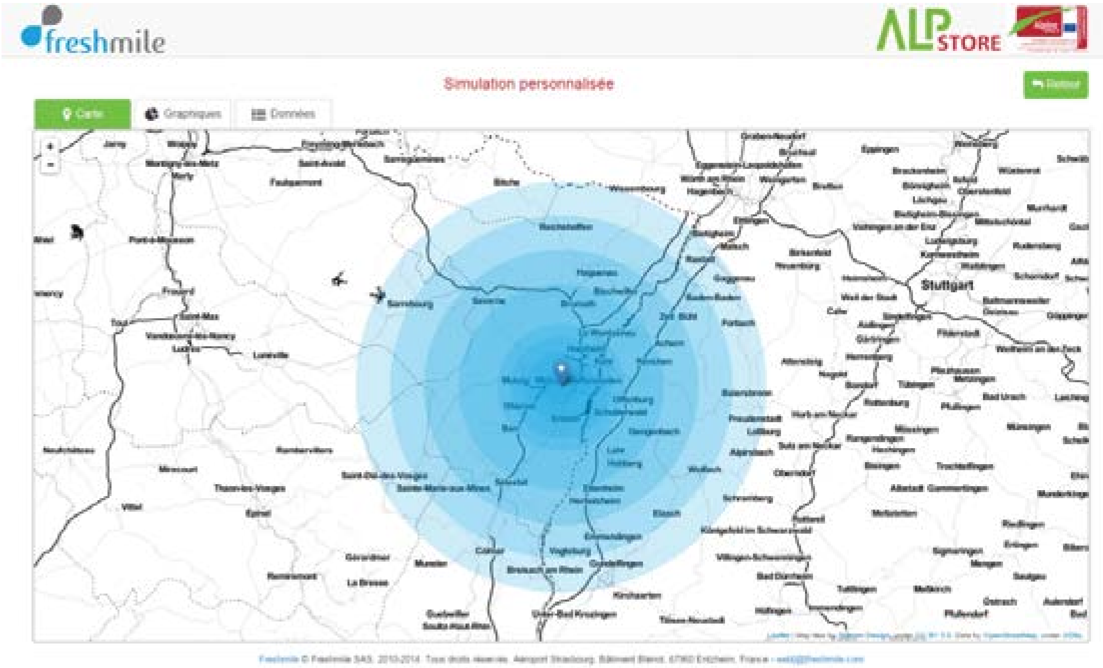


Next, 8 different mobility profiles can be selected. They all correspond to different behaviours in terms of daily distance driven.

Next, schedules can be selected. This defines at what times the simulated population is likely to drive during the day.



The red button launches the simulation, which displays the same screens as the standard scenarios shown above.



In this case, the right-hand graph displays interesting results. For such a city, the impact of EV charging would be at most 5 MW at peak times. It means that a medium-sized solar power plant coupled with a 5-15 MWh stationary storage solution would be enough to ensure some degree of energy independence to power the cars used by the residents of the city.

3 Main outcomes and benefits

3.1 Technical Findings

We found out that managing the charging process of a fleet of batteries in electric vehicles is technically feasible with existing technologies.

In particular, there is no need to invent proprietary standards or methods for communication between vehicles and charging infrastructure and between charging infrastructure and IT infrastructure. In the past, many projects were based on such proprietary developments but within the **Alpstore** project, we set as a priority to use as many existing standards as possible, so that further applications and roll-out would be feasible.

OCPP 1.5 was chosen for communication between charging infrastructure and IT infrastructure. The upcoming OCPP 2.0 standard will help reduce the amount of data transmitted while at the same time allowing more information exchanged.

Once the technical feasibility has been confirmed, as it is the case, the “real-life” feasibility lies in the quality of algorithms that match charging needs with electrical grid optimisation. This is not a problem of standard, but a problem of data collection and data analysis.

From our findings, data collected until now is too small to be able to design a real-life commercial offer on this base, but the early models designed show that there is good potential. Mobility data in particular will be used to transform the charging station and the car into connected objects, that will adapt in real-time to users’ needs.

Of course, the intelligence does not lie in the objects themselves but is rather deported in the cloud, where mobility data and charging data is collected by the apps.

3.2 Economic effects

At small scale, i.e. as long as electric vehicles represent a tiny fraction of the market, there is no real need for smart charging. There is no need from a technical point of view, as the grid can cope, and there is no need from an economic point of view, as there is nothing to monetize.

However, when charging stations are installed in constrained environments, such as underground car parks, maximum allowed power needs in many cases to be monitored and controlled. Such “local load management” is a first application of smart charging.

In theory, costs and benefits of such local load management can be assessed, but the exercise is too theoretical to be of real interest.

At large scale, there are clear economic benefits from smart charging and use of batteries as a means of mobile storage. Our first trading algorithm built at end 2012 showed such benefits, on the basis of a theoretical fleet of EVs and day+1 spot prices on electricity markets.

The question is of course when is the large scale or a sufficient threshold reached. At this stage, nobody can give any credible answer. However, the industry consensus is that 2017-2018 will see the make-or-break of electric mobility: falling battery prices alongside extended driving range will allow pure EVs to be more attractive and PHEV to become a more mainstream alternative to conventional internal combustion engines. On this basis, electrified vehicles should represent a sizeable share of the market (in terms of new sales as well in terms of rolling stock) between 2020 and 2025.

This means that taking advantage of batteries as a means of storage will become a reality and a necessity within 5 to 10 years from now.

3.3 Environmental impact

The rationale is the same for environmental impact as for economic effects: at small scale, there are no significant benefits to draw, but at large scale, EVs will exert a major impact on the electrical grid.

Our fleet simulation tool is available online at alpstore.freshmile.com. There, a fleet of EVs can be simulated at city level or at company level. The tool is programmed with a charging strategy. As an output, the user can see the number of EVs in charge at any time of the day as well as the requested peak power to feed in the batteries. These figures are helpful to imagine how local power production and energy storage would answer the need for charging these cars. Switching to locally produced renewable energy would allow to make mobility of citizens or employees environment-neutral.

The **Alpstore** simulation tool built by Freshmile is a real tool for decision-making, allowing citizens, employees, company executives, elected decision-makers to foresee how a future with environment-neutral mobility can become a reality.

3.4 Social benefits

The social benefits should be considered as an economic externality to an overall switch towards electric mobility, local energy production and storage.

There is no doubt that society benefits at large and globally from such an evolution. However, the project did not specifically assess how local communities would be impacted.

4 Conclusions

4.1 Regional potential of the tested local options

Charging strategies developed by Freshmile in the framework of the **Alpstore** project have already shown their potential for roll-out. In fact, Freshmile has been selling a commercial offer for charging service since end 2014. The first commercial charging stations were installed early 2015 in an underground car park and on a company car lot. The offer is designed to evolve towards fully-fledged price plans, such as the ones found in mobile telephony, designed thanks to the mining of data collected through the smartphone applications put by Freshmile in the hands of users.

The first commercial applications are found in Alsace and in nearby Moselle. A roll-out is scheduled in 2015 on other territories in France and in Germany.

There is no local limitation. The project output will find a concrete life in Alsace and beyond.

4.2 Follow-up plans

The most interesting part is the analysis of data collected from the mobility tracking app (Freshmile Trip) and from the charging app (Freshmile Charge). Freshmile has defined a 2-year R&D programme to create a real know-how that goes well beyond managing charging infrastructure on a technical level.

The R&D effort will be carried either on own resources or in the framework of follow-up programmes, after the end of **Alpstore**.

4.3 Transferability to other Alpine regions

As mentioned above, there is no territorial limitation. Freshmile will strive to expand to territories in France and in other countries. In other countries, partnership will local players will be sought after. Interestingly, data mining on data collected from different countries should display variations in behaviours as well as in optimisation strategies, as grid constraints and electricity prices vary from one place to another.

Freshmile looks very much forward expanding to other Alpine regions and cooperating in the future with new partners, and of course with already known partners from the **Alpstore** project.

Franche-Comté, France

Gas and Power, together for a cleaner future

Case study

Project Partner: University of Technology Belfort-Montbéliard

Authors: Ahmed Fayez Shakil, Harmouche Mohammed, Lassabe Frederic, Renaudin Christophe, Wack Maxime, Laghrouche Salah

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Case studies are contributing to AlpStore WP6

Work Package 6 Responsible: EUROIMPRESA LEGNANO s.c. a r.l.

Lead Partner: B.A.U.M. Consult, Ludwig Karg, Patrick Ansbacher, Anja Lehmann

1 Introduction

Hydrogen is the most common element in the known universe. It is a very thin gas with only 0.0007 of a pound in one gallon at ambient temperature and pressure. For comparison, gasoline is in the range of 6 to 6.5 pounds per gallon at ambient temperature and pressure [1]. Hydrogen is known for its combustible properties. However, it is more of an energy carrier than a primary energy source, as it does not exist naturally in its pure form and needs to be separated from its compounds. It holds properties that span between electricity, another energy carrier, and traditional fossil fuels. As it can be compressed and stored in large quantities, it has an important advantage compared to electricity, which, in absence of viable large scale storage systems, must be generated when needed. As an energy carrier hydrogen has some unique obstacles for its adoption. In terms of energy content, 1 kg of hydrogen is equal to approximately 1 gallon of gasoline, however as a gas its volumetric energy content is about one quarter that of the same volume of gasoline [2]. This means that high-density storage options are a necessity for some applications such as transportation.

At present, most hydrogen is produced on-site in commercial, large-scale steam methane reformer (SMR) units or electrolyzers according to the needs of the chemical and petrochemical industries. On-site production means on-purpose production with low transportation cost. For future applications of hydrogen as part of the energy grids, small scale H2 production units are inevitable. Markets prospects for fuel cell applications have initiated investment in small-scale H2 units on the prototype level to either be part of the required infrastructure for fuel cell vehicles or to feed local grids for residential stationary fuel cell systems. Small SMR or electrolyzer units require less capital investment and very little infrastructure [3].

The cost of hydrogen is a big factor for its adoption as an energy carrier. Its price will need to be competitive with that of fossil fuels, which have a great advantage in the current economic market due to their penetration and the existing environmental legislation [1,4]. In conjunction with growing penetration of renewable energy sources, hydrogen could provide a clean fuel that also might aid in grid integration of the variable nature of wind and solar resources, but only if the price is competitive.

The purpose of this study is to evaluate the prospect of using hydrogen, generated from a low power grid supplied with renewable energy sources, as a fuel for mobility in a small rural location. Using scenario based simulations developed from existing contemporary data, the research aims to support the growing case for electrolysis, demonstrate the practicality of electrolysis as a hydrogen production method as well as identify key areas that may be improved in the future.

2 Technological state of the art

This section provides a brief overview of existing electrolyzers and fuel cell technologies. It will be helpful for understanding later on, the choices made in this case study.

2.1 Electrolysis

Electrolysis is a method by which hydrogen can be produced cleanly from renewable sources. Other, fossil fuel based methods produce a variety of pollutant and greenhouse gases (CO_2, CO, NOX) that require filtering and additional carbon sequestration technologies to be clean. Electrolysis requires electricity to power the process and the source of this electricity determines the cleanliness of the process and the hydrogen fuel.

Ideally, 1kg of hydrogen requires 39.4 kWh of electricity and 8.9 liters of water at normal conditions (25°C and 1 atm). This represents the higher heating value (HHV) of hydrogen, which includes the total amount energy (thermal and electrical) to disassociate water at normal conditions. Maximum thermodynamic efficiency comes out to be 82%. The current electrolyzer efficiencies generally are in the range of 52% to 80% [3].

Alkaline Electrolysis (AEC): Alkaline electrolysis is a technically well established but cost-intensive method to produce hydrogen from water by renewable power. This process works with alkaline, aqueous electrolytes and has been used for hydrogen generation since the end of the 18th century. An alkaline solution in a tank, with two electrodes, is the most typical design. Potassium hydroxide (KOH) is generally the preferred electrolyte. Currently most commercially available electrolyzers are based on alkaline electrolyzers. The anode compartment and cathode compartment are separated by a microporous diaphragm to avoid blending of the product gases. Operation temperature of 80 °C and up to 30 bar in pressure is industrial standard.

Low Temperature Electrolysis (Polymer electrolyte electrolysis): Where high purity hydrogen is required, such as when hydrogen is used as a carrier gas to push samples through a gas chromatograph, the use of a proton exchange membrane (PEM) is necessary. PEM uses an electro chemical process to both separate the hydrogen and the oxygen. Extremely pure water is delivered on one side of the membrane, which uses an electrical current to separate the hydrogen from the oxygen, with the hydrogen diffusing through the membrane, while the oxygen is released. While the costs of this membrane material have decreased, the costs are still much higher for the PEM based systems.

PEM electrolysis is based on a solid polymer electrolyte membrane electrolyzer cell (PEMEC), which operates at around 80°C. The PEMEC is compact and the low operating temperature enables fast start-up. The produced hydrogen is clean (no traces of electrolyte) and can be delivered at pressures up to 16 bar. The PEMEC is well suited for decentralized hydrogen production with local hydrogen storage facilities.

High-Temperature Electrolysis (Solid oxide electrolysis): High-temperature electrolysis using a solid oxide electrolyzer cell (SOEC) has been discussed and tested as an interesting alternative. It is an advantage to apply part of the energy needed for dissociation as high-temperature heat at around 800-1000°C into the process and then to be able to run the electrolysis with reduced consumption of electric power. Furthermore, SOEC has the possibility of electrolyzing mixtures of steam and CO_2 into a mixture of hydrogen and CO, so-called syngas, from which artificial hydrocarbons may be produced.

High-temperature electrolysis (HTE) of steam was investigated in the 1980s by the German Dornier company in the process called “HOT ELLY”, producing hydrogen at a rate of 6.8 Nl/h (normal liters) at 1000°C and achieving an efficiency of 92% [Doenitz 1982]. Unfortunately, total production costs still remained too high, so that the project was eventually discontinued. HTE was later also tested by JAERI in a bench-scale facility with the main aim to derive design data on the process characteristics. Efficiencies remained low as compared to a high-temperature nuclear reactor [Hino 2004]. Today, the INL in the USA is conducting an experimental program to test solid oxide electrolysis cell stacks combined with materials research and detailed CFD modeling [3].

The following table shows a comparative chart of the technologies discussed.

Alkaline Electrolysis	PEM Electrolysis	SOEC Electrolysis
Well Established	High current densities and voltage efficiency	High efficiency
No noble catalysts required	Good partial load range and rapid dynamic response	No noble catalysts required
Stable	Compact system	High pressure operation
Low cost (cost effective in MW range)	High gas purity	
Low current densities	High component cost and stacks below MW range	Large in size
Gas crossover and corrosive electrolyte	Corrosive environment	Durability
Low partial load range and slow dynamics	Low durability	Still in experimental stage
Low operational pressure	Commercialization	No information on costs

Table 1. Comparative Chart of Electrolysis Technology

2.1.1 Investment cost of electrolyzers

The high capital-cost investment required for electrolyzers typically makes running them at full or nearfull load and high-capacity factors a requirement for better overall economic feasibility [5,6,7]. This is especially true because even in idling mode electrolyzers can draw 21% to 29% of their rated power [5]. If integrated with renewable sources, then generally this necessitates incorporation with the grid for variable sources or the ability to purchase off-peak electricity to boost production [7]. Electrolytic hydrogen production has several grid benefits especially when combined with renewable integration. Studies suggest that with high penetration of wind hydrogen production it will help improve utilization of these variable renewable energy (RE) sources.

2.2 Fuel cells

At present, six different fuel cell types are in varying stages of development. In general, fuel cells are categorized by the type of electrolyte used and the operating temperature. The following is a list, by increasing operating temperature order, of the most appropriate fuel cells for stationary power generation:

- proton exchange membrane fuel cell (PEMFC) (30-90 °C)
- alkaline fuel cell (AFC) (50-90 °C)
- molten carbonate fuel cell (MCFC) (650 °C)
- solid oxide fuel cell (SOFC) (800–1000 °C)

Proton exchange membrane (PEM) fuel cells and alkaline fuel cells are considered suitable for off-grid stationary applications in the range of a few hundred kW due to their fast response times and the fact they run on pure hydrogen. PAFCs, MCFCs and SOFCs use natural gas or other hydrocarbons as a fuel.

Proton Exchange Membrane Fuel Cells (PEMFC): The electrolyte of a PEMFC consists of a layer of solid polymer that allows protons to be transmitted from one face to the other. It requires hydrogen and air as its inputs, and these gases must be humidified to enable the electrolyte to function. Pressurizing the air increases performance. It operates at a temperature of about 80°C (much lower than the fuel cells mentioned so far) because of the limitations imposed by the thermal properties of the membrane. The PEMFC can be contaminated by CO, resulting in a reduction of performance by several per cent for contaminant in the fuel in ranges of tenths of per cent [8]. This technology seems ideal for Stand-Alone Power Systems driven by renewable energy sources, mainly because of its fast response times and the fact they run on pure hydrogen, which may be produced through water electrolysis.

Alkaline Fuel Cells (AFC): Although PEM fuel cells were chosen for the first NASA manned space aircraft, there were Alkaline fuel cells that took man to the moon with the Apollo missions. The success of the alkaline fuel cell in this application and the demonstration of high power working fuel cells by Bacon, led to a good deal of experiment and development of alkaline fuel cells during the 1960s and early 1970s. The major advantages of alkaline fuel cells are that the activation overvoltage at the cathode is generally less than with an acid electrolyte. Also, the electrodes can be made from non-precious metal electrodes, and no particular exotic materials are needed. The main problem with AFCs for non-space applications is the problem of carbon dioxide reactions with the alkaline electrolyte. This occurs with the carbon dioxide in the air, and would happen even more strongly if hydrogen derived from hydrocarbons (such as natural gas) were used as the fuel. The best possibility to confront these problems is to incorporate the cells into a regenerative system. Electricity from renewable energy sources is used to electrolyze water when the energy is available, and the fuel cell turns it back into electricity when needed. This way the AFCs disadvantages would be largely removed, since both hydrogen and oxygen would be generated on-site. Therefore, AFC’s advantages of low cost, simplicity, lack of exotic materials, good cathode performance, and wide range of operating temperatures and pressures, might bring them to the fore again [9].

Solid Oxide Fuel Cells (SOFC): Fuel cells of this type show higher electrical efficiencies than PAFCs and operate at much higher temperatures (up to 1000 °C); therefore their heat output can be used not only in small scale CHP applications but also in industrial processing and for producing steam to run a turbine in a bottoming cycle. Their efficiencies are estimated approximately in the 55-60% range with the possibility of introducing a gas turbine bottoming cycle to increase efficiency still further [9].

If cost targets can be obtained, the potential commercial market sector for SOFCs is also large. A market analysis of commercial building applications indicated that there were over 500,000 potential sites for SOFCs with capacities ranging from 10 – 500 kW and operating in either standalone or cogeneration modes. Most probable early customers are hospitals, health care facilities, hotels, educational and office buildings that require premium power service.

Molten Carbonate Fuel Cells (MCFC): MCFCs use a molten alkali carbonate mixture retained in a matrix, as an electrolyte. Their operating temperature is approximately 650°C, therefore useful process heat is produced. In this case, in addition to the fuel provision the cathode must be supplied with CO_2, which reacts with the oxygen and electrons to form carbonate ions that carry the ionic current through the electrolyte. At the anode these ions are consumed in the oxidation of hydrogen, also forming water vapor and CO_2 to be transferred back to the cathode. The fuel consumed in an MCFC is usually natural gas, though this must be reformed in some way to create a hydrogen-rich gas to feed to the stack [9].

The MCFC is seen by many as an ideal source for large scale power generation. One reason for this is the necessity for large amounts of ancillary equipment that would render a small operation uneconomic. There is also no requirement for expensive catalysts as in low temperature fuel cells, and a third reason is that the heat generated can be used for internal reformation of methane, a bottoming cycle and for fuel processing and cogeneration. This increases the efficiency of the fuel cell system.

3 Case study: Simulation

3.1 Scenario

In this case study, the scenario under consideration is a 1000kg PEM Electrolysis plant linked to a 1000kW renewable source integrated generation system, which powers a small 60 home village. The renewable generation is hypothesized to have largely exceed as compared to the requirements of the village as shown in the following supply-demand profile for a typical day, averaged over a period of one month.

Grid power profile												
Supply (kW)	413	520	942	984	886	571	475	426	411	404	395	402
Demand (kW)	175	225	252	281	248	201	206	183	174	171	169	166
	08:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	24:00	02:00	04:00	06:00

Table 2. Average grid power profile

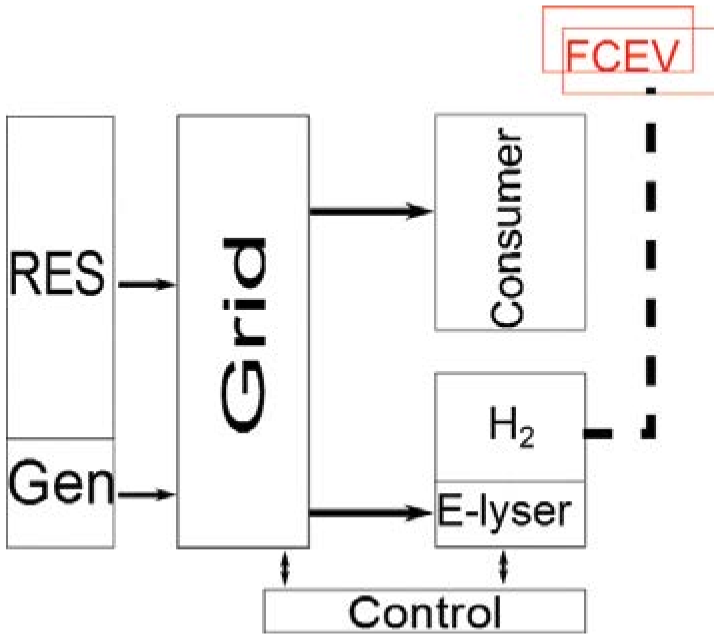
Two major assumptions are as follows:

- Summer and winter aggregate power profiles do not differ much
- A cluster of 25 PEM Fuel Cell Electric Vehicles (FCEV) of different sizes, uses and capacities (agricultural, utility, transport) exists in the village

This case study evaluates the implication of installing a 1000 kg/day PEM Electrolysis plant in order to fuel the FCEVs by using the surplus grid energy. The production takes place at a stack pressure of 30 bar and stored at 70 bar.

3.1.1 Nonfeasibility of FCEV V2G:

The initial implementation plan included Vehicle to Grid energy transfer as well. However, it is clear from existing technical data that the efficiency of grid-hydrogen-grid chain is extremely low. Therefore, it has been excluded from this study.



3.2 Costing

For the purpose, the H2A Production model [10,11] was used along with the Central Hydrogen Production from Grid Electrolysis case study, NREL Electrolysis Milestone Report 2008 for data assumptions and methods. The main aspects considered from the data are the capital cost and efficiency.

3.2.1 Grid Electricity Tarification

Source: Electricité de France

Grid electricity tarif:	Base	0.1372 €/kWh
	Peak	0.1510 €/kWh
	Off-peak	0.1055 €/kWh

3.2.2 Costing of PEM Electrolysis plant

Capacity: 1000 kg/day

Usage: 54.3 kWh/kg H2

Operation life: 20 Years

Capital cost

Source: based on [12]

Major Systems, Equipment	Baseline Uninstalled Costs	Installation Cost Factor	Baseline Installed Costs
Stacks	47,851,875	1,12	48,222,415
Hydrogen Gas Management System-Cathode system side	9,163,125	1,12	9,234,079
Oxygen Gas Management System-Anode system side	3,054,375	1,12	3,078,026
Water Reacant Delivery Management System	5,090,625	1,12	5,130,044
Thermal Management System	5,090,625	1,12	5,130,044
Power Electronics	21,380,625	1,12	21,546,185
Controls & Sensors	2,036,250	1,12	2,052,018
Mechanical Balance of plumbing	5,090,625	1,12	5 ,130,044
Other	1,018,125	1,12	1,026,009
Assembly Labor	2,036,250	1,12	2,052,018
Total	**101,812,500**		**102,600,882**

Table 3. Capital costs

Fixed Operational Cost

Source: based on [12]

Labor cost: 10 laborers, 947000 €/year, 2594.52 €/day

Estimated property tax and insurance: 2877600 €/year, 7883.83 €/day

Production maintenance and repairs: (3% capital cost): 342002740 €/year, 936993.81 €/day

Replacement Costs

Replacement costs (15% capital cost as per industry input): 15390123 €/year, 42164.72 €/day

3.2.3 Hydrogen Tarification

Production Cost per day, base electricity tariff: 372498 €/day

5 year Capital recovery cost per day: 53219.66 €/day

10 year Capital recovery cost per day: 28109.83 €/day

Nominal Hydrogen energy density: 28kWh/kg

Fuel cell energy density at 75% efficiency: 21kWh/kg

Profit factor: 1.4

Hydrogen price: 1,8 €/kg

3.3 Costs not included

FCEV deployment, pumping stations, depreciation, plant aging, altitude effects

3.4 Revised Cost

The estimated correction factor, as determined by the H2A model in presence of the non-included costs is used to revise the hydrogen price estimate [10].

Correction factor: 3

Revised Hydrogen price: 5.4 €/kg

3.5 Simulator

In **Alpstore** project, UTBM took upon the development of a smart grid simulator for evaluating the communications requirements as well as an idea of how much power could be saved by an intelligent system, based on hydrogen fuel cells. This part of the deliverable addresses four concerns. First, we describe the hardware architecture that shall be deployed in order to enable such system. Second, we discuss various network issues and their workaround. Third, we describe the software components required for being able to manage the whole system. Fourth, we present the choices made to implement a simulator, whose goal is to provide performance expectations based on numerical data. In the proposed work, we base our models and architectures on the ISO/IEC 15118 standard, which addresses smart grids based on battery electric vehicles. Given the differences between battery-based electric vehicles and fuel cell-based ones, we adapt the architecture to our environment and its specifics.

3.5.1 Architecture

In the ISO/IEC 15118 standard, charging from and discharging to the grid is performed by the same device: the vehicle. Indeed, the rechargeable battery chemical structure enables it to, either generate energy, or to reverse the process and store the energy.

On the opposite, in a fuel cell electric vehicle, a high pressure hydrogen tank injects H2 into the fuel cell and produces energy and water. However, such vehicles cannot reverse the process by themselves because they do not embed a hydrolyzer. Therefore, in our architecture, producing and consuming the electrical energy is split into two different devices: the vehicle, and the hydrolyzer.

The remaining parts of the system are similar to that of the ISO/IEC 15118 standard: it consists in an aggregator, i.e. a device that communicates with all vehicles, hydrolyzers, and the grid, and the grid itself, which provides energy to all the devices. Since the grid contains a variable part of renewable energies, its production is unstable, therefore requiring to optimize the whole system for limiting the side effects of such fluctuations.

The aggregator gathers periodic data from all the other devices, including the grid, in the system. It maintains a full list of the devices status. Based on the global system knowledge, it commands to respectively the hydrolyzers and the vehicles, to respectively take grid energy to generate hydrogen and to use their hydrogen tanks content to generate energy to be pushed on the grid.

In the remaining parts of this report, we refer to the fuel cell electric vehicle as FCEV.

We also define the following elements, based on ISO/IEC 15118 standard:

- EVCC: Electric Vehicle Communication Controller, in charge of the high level communications transmitted by the vehicle,

- HCC: Hydrolyzer Communication Controller, in charge of the hydrolyzer's high level communications,
- AGG: the aggregator.

Both communication controllers are able to act on the device state by communicating with other organs (fuel cell, etc.).

3.5.2 Network operations

As proposed in the previous section, the aggregator can communicate with the hydrolyzers, the FCEV, and the grid, and *vice versa*. In this section, we propose a network architecture and discuss it compared to actual wide area networks (WAN) capabilities.

3.5.2.1 Layer 3 Protocol

The ISO/IEC 15118 requests that the software embedded in the system devices are connected on a network with a IPv6 addressing space. Since a smart grid system is very likely to be connected through the Internet, and since the Internet is still mainly IPv4, we propose that the system shall be able to operate either in IPv6, or in IPv4[1]. The regular network communications shall be on a peer-to-peer basis, i.e. each device shall be able to address directly its destination. We discuss later how to mitigate problems when using network address translation (NAT) between part of the devices.

3.5.2.2 Expected limits

The Internet of Things and mobile devices, such as embedded computers inside vehicles, expect to be able to communicate with other devices on a full duplex link. As long as we remain in the client-server scheme (i.e. the EVCC requests some data from the aggregator, the later sends back a response), no problem will arise.

However, the system needs the aggregator to be able to send commands to the HCC, and to the EVCC. Such commands are time-sensitive because they must trigger an overall optimal behavior in the grid when its energy production is fluctuating. Therefore, the aggregator shall be able to send data to the HCC, and EVCC without these ones having requested the data.

In a IPv6 network, there are enough addresses to provide every device with several public addresses. In IPv4 networks, there is unfortunately not enough addresses, especially on the Internet. While the IETF RFC 1918 partially addresses the problem by defining private addressing spaces and network address translation (NAT), these solutions do not allow to initiate a connection from outside the NAT to an inside device. In such cases, several solutions are possible for the HCC and the EVCC:

- WebSockets: it's the preferred solution, since it allows to get a full duplex connection between the client and the server as soon as the client requested one data from the server. Then, the server can send information to the client without restrictions,
- Long polling: for each request, the server either responds with a command, or put the client's request "on hold" until a command requires to be sent to the client. This solution's drawback is to require much resources.

[1] However, for security reasons, any IPv4-only implementation shall avoid calls to gethostbyname and gethost-byaddr functions.

3.5.2.3 Messages

In this subsection, we define the messages between the devices (aggregator – EVCC, and aggregator – HCC). The messages are represented as an XML string, according to the ISO/IEC 15118 standard, but they could as well be represented on another format (e.g. JSON, ASN1 with BER encoding, etc.)

FROM	TO	Name	Data
EVCC	AGG	Status update	Vehicle id, status, current generated power, tank level (percent)
AGG	EVCC	Start generate	Vehicle id, power
AGG	EVCC	Stop generate	Vehicle id
AGG	EVCC	Change power	Vehicle id, power
HCC	AGG	Status update	Hydrolyzer id, status, current used power, tank level and number
AGG	HCC	Start hydro	Hydrolyzer id, power
AGG	HCC	Stop hydro	Hydrolyzer id
AGG	HCC	Change power	Hydrolyzer id, power

The vehicle has a status among the following ones: IDLE, PLUGGED, DISCHARGING, DRIVING, REFILL. The hydrolyzer statuses are following: INACTIVE, GENERATING. The devices exchange messages with the following rules:

- The EVCC *status updates* are sent every 30 seconds. On top of that, if anything in the vehicle status changes, it sends a status update and resets its counter to zero,
- The aggregator sends a *start generate* message to the EVCC when the EVCC is PLUGGED and the grid does not provide enough power to the users,
- The aggregator sends a *stop generate* message to the EVCC when the EVCC is DISCHARGING and the grid provides enough power to the users,
- The aggregator sends a *change power* message to the EVCC when the EVCC is DISCHARGING and the aggregator wish to adapt the power contribution of the target vehicle to a grid fluctuation,
- The HCC *status updates* follow the same rule than the EVCC ones,
- The aggregator sends a *start hydro* message to the HCC when the HCC is INACTIVE and the grid provides too much power to the users,
- The aggregator sends a *stop hydro* message to the HCC when the HCC is GENERATING and the grid does not provide too much power to the users,
- The aggregator sends a *change power* message to the HCC when the HCC is GENERATING and the aggregator wish to adapt the power consumption contribution of the target hydrolyzer to a grid fluctuation.

Note that every message requires an acknowledgment from its destination.

3.5.3 Software architecture

Since the goal of the project is not to build a real system, but rather to propose evaluated solutions to the energy transition, we did not implement all the physical components. We chose to implement a software simulator, running by steps to keep everything synchronized. The simulator mainly provides components for the vehicles, the hydrolyzers and a main program which also acts as the aggregator. Figure 1 shows the main classes architecture.

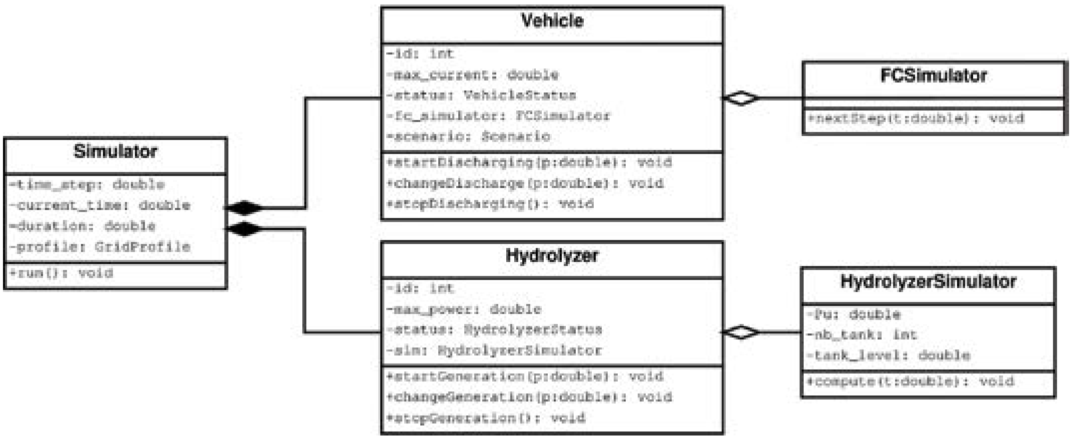


Figure 1: Simulator class diagram

The *Simulator* class is the root class in the application. It is in charge of simulating the aggregator, reading the grid profile, and managing the simulation iterations. Its main attributes are:

- *duration:* the duration of the simulation in seconds,
- *current_time:* the current time being simulated, between 0 and the duration,
- *time_step:* the duration of each simulation step,
- *profile:* the grid load profile, defined by how much power is missing or over-produced.

The only notable method is run, which starts the simulation at time 0 and runs it until it reaches duration seconds. The simulator is also composed of a variable number of vehicles and hydrolyzers.

In the vehicle, there are 5 main attributes:

- a unique *id* to identify the vehicle,
- a *max_current* that the vehicle is able to output on its engine or on the grid,
- its *status*, indicating what it is currently doing,
- a *simulator*, which simulates the fuel cell inner operations,
- a *scenario*, which describes what the vehicle does along the simulation (driving, etc.).

The *FCSimulator class* is an accurate fuel cell operation model. It computes various physical measures based on the fuel cell current variables. The *FCSimulator*'s notable method is the *nextStep*, which take a time as parameter. This method then calls the internal mechanics of the fuel cell simulator to update all the internal variables.

The *Hydrolyzer* and *HydrolyzerSimulator* classes have the same relationship: the hydrolyzer is defined by:

- id: its unique identifier,
- max_power: its maximum input power, used to generate hydrogen,
- status: its current status, indicating whether it's idle, or generating hydrogen,
- sim: its hydrolyze reaction simulator, which implements the chemical reaction formulas based on its variables.

Both *Hydrolyzer* and *Vehicle* have three methods corresponding to the three commands that the aggregator can send.

3.6 Models

Both *FCSimulator* and *HydrolyzerSimulator* are based on both models described below.

The PEM fuel cell is an electrochemical device which produces electricity due to a chemical reaction between oxygen and hydrogen. The PEM Fuel Cell system in an automotive application consists of 6 subsystems, airfeed supply system, hydrogen supply system, coolant system, power management system, fuel cell system and the control system [13, 14].

The air feed system is represented by three parameters, the compressor speed, the compressor flow rate, the supply manifold pressure and the relative humidity degree in its manifold.

The hydrogen supply system is represented by two parameters, the hydrogen pressure supply to the anode side and the relative humidity degree in its manifold.

The coolant system is represented by the temperature variations inside the fuel cell.

The power management is represented by the fuel cell demanded load and its voltage.

The fuel cell is divided into three parts, cathode side, anode side and membrane. The cathode side is represented by the three majority's gases in the cathode channel, oxygen, nitrogen and vapor. The anode side is represented by the gases inside the anode channel, hydrogen and vapor. The membrane is represented by the reacted flow rate and the water content in the membrane.

The control system is objective to operate the fuel cell on its optimal value in order to have a good performance and protect the fuel cell and the auxiliaries from damaged. The parameters which are requested to be control are: compressor flow rate, hydrogen pressure, fuel cell temperature, relative humidity degrees and the power produced by the fuel cell.

The electrolyzer is an electrochemical device which produces hydrogen by separating the water molecules by applying an electrical power. The electrolyzer can be represented by, the inlet water flow rate to the electrolyzer, the pressure inside the anode and the cathode side, the electrolyzer temperature, the electrical power needed to the chemical reaction, the water content in the membrane and the produced hydrogen flow rate.

3.7 Configuration

The simulator requires a configuration to be able to run. Basically, every system property has to be defined in the configuration for the simulator to be able to compute the system operation over time.

A configuration is described by a XML file consisting of several sections:

- The overall system configuration has the following parameters: *length* and *step*. Parameter *length* is an integer value, setting the simulation length in seconds. Parameter *step* is a floating point value, setting the simulation time step, in seconds. Therefore, the simulation has to run *length / step* iterations. After this main element, the following three sections are the grid profile, the vehicles list, and the hydrolyzers list.
- The first section defines the grid profile. It consists of pairs of value, *time* and *overhead*. Parameter *time* defines when the current grid production is active. It is defined as a floating point value, in seconds. Parameter *overhead* defines the grid overproduction, between the corresponding time and the next time present in the scenario. It is either positive (grid is producing more than

consumed), or negative (grid is producing less than consumed), or zero (production and consumption are balanced). Every change in the grid profile requires one pair of time, overhead.

- The second section consists of one or more vehicles. Each vehicle has two kinds of configuration:
  - Its global configuration: it consists of its *id, max_current, charge, pressure, volume, and cathode*. All parameters define the vehicle and fuel cell properties, used to initialize the fuel cell model. The vehicle parameters are *id* and *max_current*, used by the aggregator to identify and address the vehicle and know its *current* (Amp) limit (in case V2G would be required). The other properties are the fuel cell and H2 tank initial states (tank fill percentage (*charge*), tank *pressure* (bars), tank *volume* (cube meters), and *cathode* pressure (bars)).
  - The vehicle usage profile. It is composed of sets of 3 values, *time, type, and current*. Each event starts when the simulation date reaches *time* seconds. For each event, its *type* is defined (among DRIVE, IDLE, PLUGGED) and the corresponding *current* required by the vehicle. When in IDLE or PLUGGED, *current* is ignored. Types IDLE and PLUGGED differ by the fact that, while doing nothing in both cases, the PLUGGED vehicle could perform V2G, while in IDLE, it is not electrically connected to the grid, therefore, no interaction with the system is possible.
- The last section defines the hydrolyzers. Each hydrolyzers requires the following properties: *id, max_power, pressure, volume*. The aggregator uses the *id* and *max_power* to address the hydrolyzer and know its power limit. The power limit is the maximum power that can be used by the hydrolyzer to generate hydrogen. Parameters pressure and volumes are used internally by the inner simulator to compute how much hydrogen in how many tanks will be produced.

3.8 Results

The simulator monitors the vehicles and hydrolyzers states, as well as the grid production. Its optimization are currently straightforward:

- When the grid does not provide enough power, the vehicles supplement the production based on the current rule: if the vehicle is plugged to the grid, and it contains hydrogen, then it produces electricity to the grid, capped by the maximum power it can output with its FC engine.
- When the grid produces too much power, the hydrolyzers start to generate hydrogen, capped by their maximum input power.

Different scenarios were generated using the power profile described in Table 2 as a base characterization for surplus energy. Then different driving profiles were used to simulate the FCEVs in use, thereby representing the consumption of Hydrogen. Finally, variations in grid load introduced to capture the effect of varying load on the system. For the FCEVs, it is assumed that they do not exit the agglomeration, limiting their speed and hence their mobility to:

FCEV consumption: 123.9km/kg (4th generation fuel cell benchmark)

This assumption is used in order to evaluate the influence of fuel cell dynamics over the hydrogen consumption. The consumption rate also varies in function to the type of vehicle, considering 20 personal vehicles limited to 50km/h, 5 utility vehicles limited to 30km/h.

3.8.1 Base characterization: Surplus energy

Assuming that vehicles are in function and all the surplus energy is used to produce hydrogen, the base profile given in Table 2 results in a net production of 80.7 kg per day. In the following scenarios, the simulation starts with an initial set of half-empty vehicles at 08:00 and continues through the day using time slots to calculate the net hydrogen consumption. Each time slot shows the number of vehicles at the end of its execution (08:00 shows the traffic status at 08:59) and the kilometers accumulated within it. The vehicles are not obliged to respect the specific slots; they can stop in the middle or continue into the next. The remaining hydrogen is indicated at the end and can be used in the initialization of the next simulation run.

3.8.2 Run 1 Average traffic

Driving profile 1												
Vehicles	18	15	10	4	6	17	19	15	1	0	0	10
Kilometers	375	520	348	60	110	185	610	430	20	0	0	50
	08:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	24:00	02:00	04:00	06:00

Net Hydrogen Consumption at base value: 21.85kg

This run represents a typical traffic loading pattern, peaking at rush hours. During off hours of the day, the traffic is mainly composed of utility vehicles whereas the circulation is almost finished during late night. The key factor to be seen here is that base production of 80.7kg largely supersedes the consumption.

3.8.3 Run 2 Heavy traffic

Driving profile 2												
Vehicles	10	15	18	17	21	14	15	11	8	3	0	5
Kilometers	840	1085	1950	1520	2450	1075	945	105	75	10	0	15
	08:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	24:00	02:00	04:00	06:00

Net Hydrogen Consumption at base value: 81.27kg

This run shows an extreme augmentation of traffic, such as usually seen during vacations. The net hydrogen consumption exceeds the base production value, but can be compensated for example, if there is an initial hydrogen stock from the previous days.

3.8.4 Run 3 Grid failure

Grid power profile												
Supply (kW)	413	520	510	500	487	498	475	426	411	404	395	402
Demand (kW)	175	225	348	352	248	251	206	183	174	171	169	166

Net Hydrogen Production at diminished value: 51.07kg

This run includes a failure in the grid, restricting the power supply to 500kW. The production remains sufficient to cater for average and rush traffics; however a massive rush would create a serious shortage. Given the size of the locality under consideration, it can be seen that the overdimensioning is essential if the sole source of hydrogen is the electrolyzer plant.

4 Conclusion

This case study was based on a simulation of hydrogen production and consumption in an ideal futuristic village equipped with sufficient renewable resources to exceed its needs and with accessibility of fuel cell electric vehicles. Some critical points come to light immediately and are discussed below.

In spite of overlooking certain factors, the cost of Hydrogen could not be reduced significantly. This scenario was created based on the state of the art examples and data available; therefore the cost prediction is not far off. In this respect, it may be concluded that at the moment, electrolysis alone may not be a prime mover towards promotion of hydrogen based mobility. Indeed, this can be remedied by incorporating other methods of hydrogen production.

In order to meet the mobility demands using just the electrolyzer, the system needed to be overdimensioned and required a non-realistic difference between the electricity supply and demand. This however, may well be the case in 20 years, with the rapid increase of renewable sources in the local and national grids in Europe. Whether the hydrogen energy conversion chain improves in its efficiency is yet to be seen. New developments are to be seen in high temperature and high pressure technologies that are in experimental stage at the moment.

Finally, what constitutes as an important perspective of this study is the necessity of practical case studies, borne out of physical pilots. Indeed recapitulated technical data needs to be concurrent with location-specific issues in order for it to exploitable during policymaking. The results of this study have demonstrated the technical viability of electrolysis as an energy storage process for enchaining electricity with mobility. Investments and political interest can make it economically viable.

It should be noted that these results have been achieved using published data. Its accuracy is only as good as that of the available data and it may also be influenced by local geopolitical situations.

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Vorarlberg, Austria
EVective storage
Case Study

Project Partner: Voralberger Elektroautomobil Planungs-und Beratungs GmbH

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Case studies are contributing to AlpStore WP6

Work Package 6 Responsible: EUROIMPRESA LEGNANO s.c. a r.l.

Lead Partner: B.A.U.M. Consult, Ludwig Karg, Patrick Ansbacher, Anja Lehmann

1 Storage technologies for the region Vorarlberg - general frame conditions and objectives

1.1 Actual and future regional energy system

Energy Situation Vorarlberg

Vorarlberg is a region where hydro power plays an important role in the production of electricity. More than three quarters of the sold electricity in Vorarlberg comes from hydro power plants. The rest of the sold electricity comes from gas fired power plants (8 %), wind (4 %) and biomass (4 %). The electricity of these power plants is purchased by the Vorarlberger Kraftwerke AG. Vorarlberg has therefore no nuclear, gas or oil fired power plant in operation. The CO_2 emissions with 28 g/kWh are lower compared to the national and the European level, because of the high amount of renewable energy sources. The share of renewable energies in the heating sector is also high. The biggest share has still gas followed by renewable sources like geothermal, biomass and solar thermal. The rest of the heat consumption is covered by oil.

Mobility Situation Vorarlberg

The total number of cars in 2012 has been 193,000. The share per inhabitant is therefore relative high. Vorarlberg has been one of the first model regions for e-mobility in Europe and the first one in Austria. Today are about 450 BEV on the roads and 150 public charging stations have been built by the Vorarlberger Kraftwerke AG. The BEVs are exclusively charged with renewable energies, which have been additionally built during the VLOTTE project in form of photovoltaic power plants and a small hydro power plant. The EVs in Vorarlberg have proven their suitability for daily use.

Storage Situation Vorarlberg

Vorarlberg is located in the Alps. The electricity production is therefore characterized by storage and pump storage hydro power plants. The amount of water from the lakes Silvrettasee, Kopssee, Vemuntsee and Lünersee is processed in several stages. This means that the water is used a bunch of times to produce control and peak energy. The hydro power plant group of Illwerke operates as a water and energy management unit. The nominal capacity of the turbines in 2012 has been 1,812 MW and the input power of the pumps has been 999 MW. The annual output of all pump and storage power plants has been 2,722 GWh. Other storage systems are not in operation.

Future Energy System

Electricity will have a special role in the energy system of the future. A key element in supplying energy in the future involves a drastic expansion of tapping renewable energy from sunlight, water and biomass. It is to be expected that the future energy supply of households and industry will increasingly be based on electricity. Vorarlberg is moving towards an “electricity society”, i. e. other sources of energy will progressively be supplanted by electricity (e. g. by using heat pumps or moving into e-mobility). The demand for electricity will therefore rise in these areas. In addition to that energy efficiency will also play a major role. The combination between energy savings, energy efficiency and tapping renewable energy sources will be characteristic for the future energy system.

Future Storage System

The future energy storage system in Vorarlberg will be characterized by hydro storage and pump storage power plants like it is today. With this storage system short term and long term aspects can be covered. With the planned construction of Obervermuntwerk II further steps are taken to a sustainably integration and continued expansion of renewable energy in Europe. The mass rollout of electric vehicles will also lead to an additional storage capacity till 2050. Other storage systems like battery storages will become more and more interesting in the near future. It is hard to predict how big the actual potential for these storage systems really is. Beside the discussion about storages for the electricity system, storages for the heat production play an important role in the future energy park of Vorarlberg. In this sector the decentralized storages will play a major role. Especially solar thermal, geothermal and biomass heating systems need storages to provide heat all day long. It will be necessary that all these heating systems are equipped with these water storages. The capacity for heating storages will therefore also increase.

1.2 Regulatory framework

Energy Autonomy Vorarlberg 2050

Energy autonomy Vorarlberg is the central energy policy program of the State of Vorarlberg, which was initiated in 2007. Austria's westernmost province, Vorarlberg, had set itself an ambitious target: achieving energy self-sufficiency based on renewable energy sources by 2050 and so becoming independent of price rises and supply shortfalls affecting oil and natural gas. This long-term strategic goal has been supported in a unanimous decision by all political parties.

The process "Vorarlberg's Energy Future" is intended to implement a sustainable energy supply system step by step and make a valuable contribution to climate protection. This long-term strategy relies upon four pillars: energy saving and energy efficiency, increased employment of renewable energy, new mobility strategies and investment in research, development and education.

In a first phase, a vision process was carried out in ten workshops. Based on these results concrete measures, how to implement the vision process, have been developed. In this participatory process experts but also representatives of interest groups have been involved. In the near future, by 2020, Vorarlberg wants to achieve at least the energy policy goals set by the EU (20-20-20). So the task was to draw up an action plan that describes specific measures on the one hand for the next about

10 years, which are suitable to achieve the 2020 targets and on the other hand can classify the goals of the energy autonomy. In 2011, an extensive portfolio of measures was adopted, the so-called "101 measures for our grandchildren".

2 Pilot projects "2nd Use Battery" and "Embroidered Battery"

In 2009 Vorarlberg started with one of the biggest e-mobility projects in Europe. The main goal of the VLOTTE project was to bring electric vehicles to the market. Building up public charging infrastructure and renewable energy facilities have also been two important issues in the project.

In the end of 2014 there were already roundabout 450 EVs in Vorarlberg registered. This amount of cars doesn't have a big impact to the grid at the moment. But this could change very fast, especially when even more EVs run on Vorarlberg's roads. A higher amount could stress the grid at hot spots like shopping centers. The expansion of renewable energy sources like photovoltaic proceeds also very fast. In the future it will be necessary to bring the production and the demand side together to ensure a stable energy supply. Battery systems could be one possible way to support that approach.

Another important question will be "What will happen with the batteries from the EVs?" Second use applications could be another possible use case for energy suppliers like Vorarlberger Kraftwerke AG in the future. For that reasons VLOTTE decided to build up a pilot in whom **2nd Use Batteries** from EVs will be used to store and to balance the energy of a photovoltaic power plant.

At the moment battery systems based on Lithium-Ion or ZEBRA have the highest market share in EVs. New battery concepts could become more and more interesting in the near future, for example to extend the range of electric vehicles. For that reason VLOTTE supports the development of a new battery system based on embroidered materials in a second pilot activity.

Both pilots are developed in a first step independently from each other. After both of them have proven their functionality they shall be merged into one system.

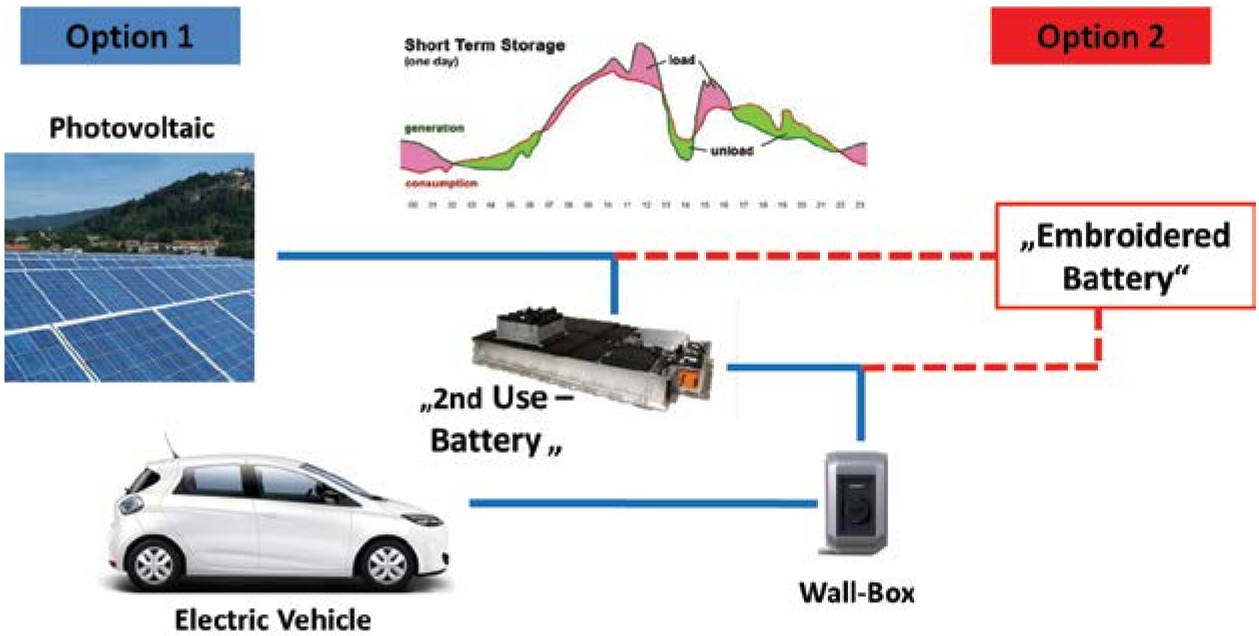

Figure 1: Pilot Activities of VLOTTE

2.1 Characteristics of the field test

"2nd Use Battery"

Location

The pilot will be implemented at the Vorarlberger Kraftwerke AG in Bregenz. The electric vehicles (EVs), which are mainly in use for daily business trips, are placed in a parking garage. This parking house is equipped with a photovoltaic system and with adequate charging infrastructure. The goal of the pilot activities is to manage supply and demand side with stationary batteries. The best prerequisites for implementation are therefore given at the chosen place.

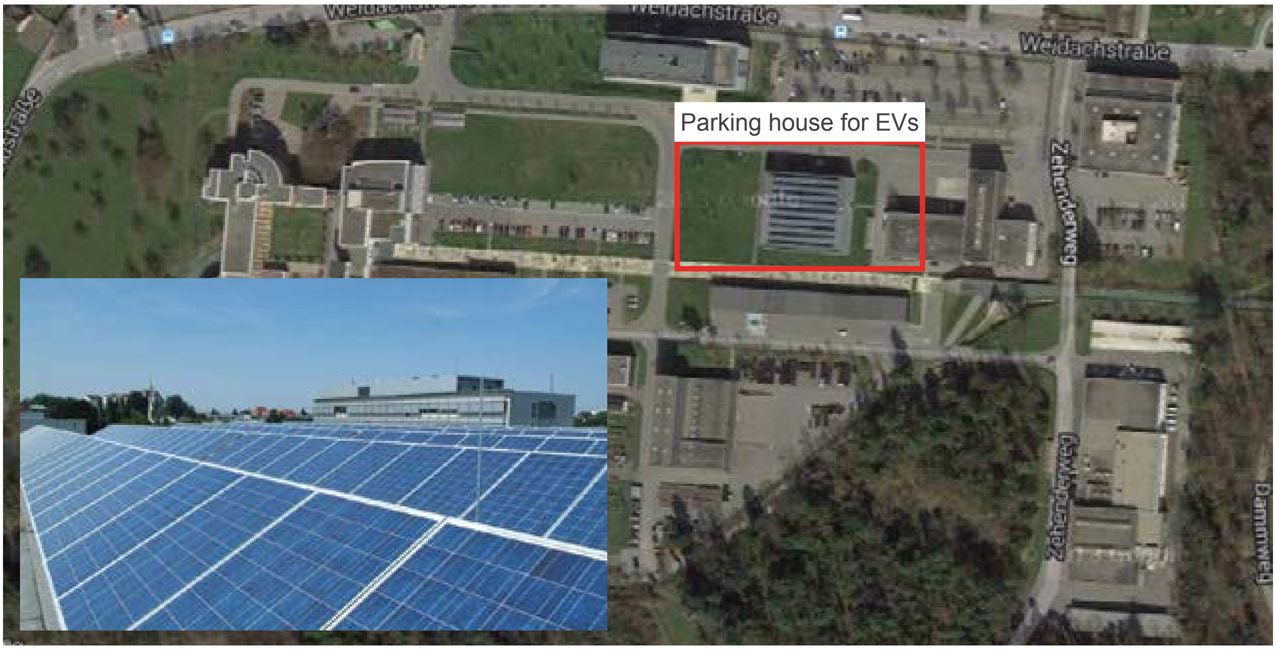

Figure 2: Location Vorarlberger Kraftwerke AG

Purpose of the pilot

The first pilot activity "2nd Use Battery" handles with the topic of shifting renewable energy production with 2nd Use Batteries from EVs. The main goal of this pilot activity is to show how 2nd use batteries work under real life conditions and to demonstrate the technical feasibility of such systems. In a further step the battery shall be implemented into a Virtual Power Plant (VPP) in the Smart City Rheintal project, which is funded by the Climate and Energy Fund Austria.

Technology

The used batteries and the equipment came mainly from two broken electric cars. The used technology for the battery system is a ZEBRA battery (molten salt battery). The battery uses molten salts as an electrolyte and offers both a high energy density and a high power density. These thermal batteries can be stored in their solid state at room-temperature for long periods of time before being activated by heating. Rechargeable liquid metal batteries are mainly used for electric vehicles and potentially also for grid energy storage, to balance out intermittent renewable power sources such as solar panels. They have therefore been the best choice for this application.

Figure 3: Location Vorarlberger Kraftwerke AG

Objectives

The main goals of this pilot are

- Demonstrate the feasibility of 2nd Use Batteries of EVs as a storage systems
- Integrate the battery system into a Virtual Power Plant
- Operate the battery system in a Virtual Power Plant with developed algorithm

Regional Stakeholders

The battery system was developed together with partners from the region. The Vorarlberger Kraftwerke AG provided two ZEBRA batteries and the charging equipment of two broken EVs. VKW was also responsible for the total implementation process. E-Car Services is a specialist in repairing EVs based on ZEBRA batteries. They constructed and implemented the battery storage in the parking house of the VKW. In a last step the University of Applied Science Vorarlberg (FHV) developed a control system and programed the algorithm to manage the battery system. They also took care about the implementation to the Virtual Power Plant in the project of Smart City Rheintal.

"Embroidered Battery"

Location

The Embroidered Battery is developed and constructed in Dornbirn at the Research Institute of Textile Chemistry and Textile Physics of the University of Innsbruck. The battery is developed under laboratory conditions.

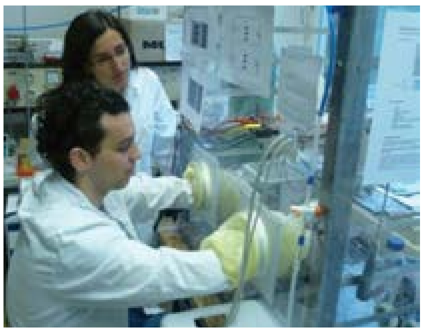

Figure 4: Research Institute of Textile Chemistry and Textile Physics of the University of Innsbruck

Purpose of the pilot

In the second pilot activity "**Embroidered Battery**" a new type of battery will be developed and tested. The goal is to prove the theoretical assumptions with a prototype of such a battery.

The application of technical embroidery in electrochemical cells thus allows:

- Construction powerful battery systems
- Rapid charging is possible
- Higher peak power can be delivered
- More concepts cathode during charging

Therefore, a significant weight reduction in the electrochemical energy storage can be expected. This can lead to better battery systems with higher energy density.

Technology

In standard battery applications a metal foil serves as current collector. The active mass is coated on the surface of the foil and then charged/discharged through the transfer of electrons form the foil to the active mass. The metal used to manufacture the foil depends on the electrode reaction and is chosen with regard to following aspects: chemically stable, no passivation, no side reaction, sufficient conductivity, affordable costs. In a standard $LiFePO_4$ accumulator the cathode is manufactured from aluminium, while the anode is made from copper.

A mixture of $LiFePO_4$, carbon and organic binder is used to manufacture the cathode. The addition of a few percent of carbon is required to achieve sufficient conductivity inside the coating as a requirement to charge/discharge all parts of the active mass.In case insufficient conductivity is observed inside the active mass, the coating is not fully available for charge/discharge cycles, which then lowers the capacity of the battery as only a share of the active mass is used. In the case of the $LiFePO_4$ battery the anodic reaction is an intercalation of Li-ions into graphite layers, thus the active mass at the anode is formed by carbon, with a copper foil as plane current collector.

To avoid short circuits, both half-electrodes are separated by a porous diaphragm which permits transfer of charged ions (Li+), however avoids contact of the two solid electrodes. The charge transfer in the electrolyte is achieved by movement of Li+ ions, thus a $LiPF_6$ solution in propylenecarbonate / dimethylcarbonate serves as conduction electrolyte. To permit transfer of Li+ ions from the porous cathode to the anode both solid electrodes have to be porous.

The electrodes thus have to exhibit a number of properties, which are in conflict to each other:

- mechanical stability
- good electric conductivity
- high porosity for Li+ transport
- high density of active components (e.g. $LiFePO_4$)

The conductivity of the active mass limits the possible thickness of the layer formed at the surface of the metal foil. Thus typical thickness of a battery electrode material is in the dimension of 50 µm with a mass of 20 mg/cm2. An increase in thickness of active layer could have significant advantages for the overall capacity of a battery concept. An increase of the conductivity by addition of higher amounts of carbon is not productive as this indirectly reduces the effective share of redox-active component in the electrode layer.

When thicker electrode layers should be used, the current should be fed directly to the place of the active material in the layer. This can be achieved by use of current collectors for which different concepts have been proposed in the literature e.g. porous metal foams, carbon mesh, metal wire fabric.

Every concept to construct a porous conductive structure has specific advantages but also disadvantages, e.g. porous structures are difficult to prepare and the homogenous filling with active cathode material is difficult, similar problems of filling are observed when fibre mesh or wire fabric is used. This material has to be cut into the final form which then leads to risks of short circuits through the open fibre ends present near the cut sides.

Embroidered Materials

A flexible approach to produce a conductive structure e.g. from aluminium wire or copper wire is technical embroidery. By technical embroidery conductive 3D-structures can be produced with high flexibility form a wide range of different materials.

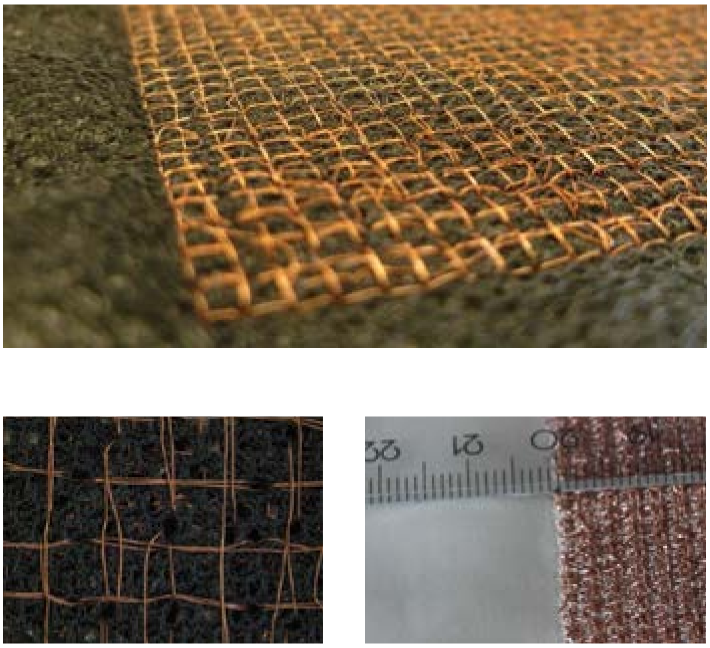

Figure 5: 3D Electrodes

Mathematical Approach

The thickness of the active material layer on the electrode directly will influence the performance and the overall capacity of a battery. For a given application the capacity will grow with thickness of the active material layer, however this will not be a linear increase as also the weight for housing and non electroactive components will grow. While the increase in capacity can be assumed to be directly proportional to the thickness of the layer, the increase in mass of the non-active components will be lower.

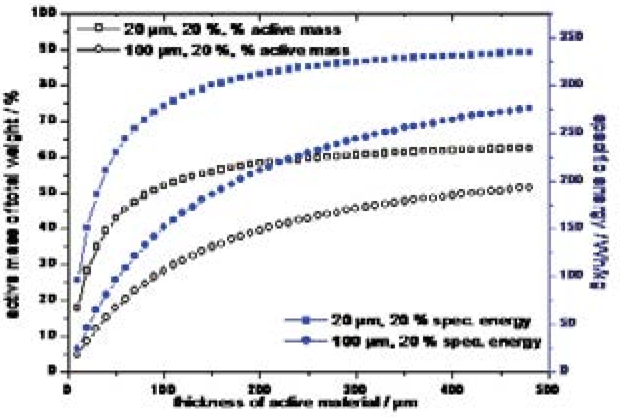

Figure 6: Mathematical Approach

A simple mathematical formulation for the estimated capacity can be based on standard battery data, which then are extrapolated for growth in thickness of the active material. The potential of embroidered current collectors can be assessed by numerical simulation of cell performance and weight as function of active layer of electroactive material. In the presented calculation the following basis was made for the calculations:

For a given construction 28 % of the total cell weight was assumed to be the active mass, 72 % of the cell weight are non-active components, housing, electrolyte, carbon, separator and current collectors. A standard cell was defined with a certain thickness of the active layer, which exhibits an specific energy of 150 Wh/kg of cell respectively an energy density 225 Wh/l. The change in active layer thickness was considered to increase the mass of non-active components by a certain percentage of the increase in active mass, thus not the full increase in thickness the active system will be reflected in the energy density data.

Experimental Assessment of embroidered electrodes

In the experimental work at the institute two researchers investigate the performance of wire based current collectors in comparison to the plane electrodes as reference system. The electrodes are studied under low oxygen and low moisture atmosphere in an Ar-chamber to avoid uncontrolled effects due to Li-corrosion. Charge discharge curves have been investigated for electrodes with increasing layer thickness and thus increasing mass of active material, to evaluate the advantages of a wire based current collector.

Objectives

The main goals of this pilot are

- Demonstrate the feasibility of embroidered battery
- Built new battery based on embroidered materials
- Merge battery with 2nd Use Battery

Regional Stakeholders

The Research Institute of Textile Chemistry and Textile Physics of the University of Innsbruck in Dorn-birn is responsible for the implementation. They are supported by other regional textile com-panies (Smart Embroideries) in Vorarlberg.

2.2 Storage technologies and frame conditions

The developed storage systems have proven their functionality but they are still prototypes. Such systems will play a minor role in the storage market in Vorarlberg. The storage system number one will still be hydro storage and pump storage power plants in the future.

2.3 Research design and schedule

The project started with a detailed planning process of both two pilot activities. In a first phase basic concepts have been developed through a brainstorming process before the detailed planning of the pilot activities started. In a next phase the hardware and software for the realisation of the pilots were organized before the construction of the pilots began. Both pilots have been developed independently from each other. At the end of the project the pilots should be merged to one.

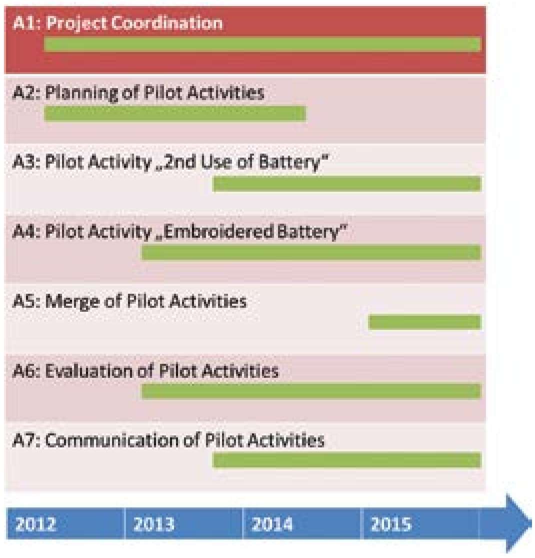

Figure 7: Schedule of Pilots VLOTTE

2.4 Implementation process

Both pilots "2nd Use Battery" and "Embroidered Battery" could be implemented in time and with the planned budget. Both of them have proven their functionality but they are still prototypes. The development of prototypes makes the implementation even more difficult. Main reason for that is the missing experience with such systems. This makes also the planning process more time-consuming and leads to deviations in the implementation process. That is also a reason, why the evaluation process and the merge of both systems had to be postponed in the project.

3 Main outcomes and benefits

The main outcome of both pilot implementations was the demonstration of the technical feasibility of new battery systems. Both of them have different use cases.

Pilot 1: "2nd Use Battery"

Within the **Alpstore** project the following function and uses cases could be implemented.

- Detailed concept of "2nd Use Battery" developed
- Battery storage system prove functionality
- Active charge management in use
- Shifts of power at location demonstrated
- Implementation of "2nd Use Battery" to VPP

Beyond the general use cases the "2nd Life Battery" fulfills other technical requirements. The battery storage can be charged with electricity from the local PV power plant during the day and will be discharged in the night. EVs in the parking garage can therefore be charged by night with the self-produced electricity from the PV power plant. Through the integration into a Virtual Power Plant (VVP) the storage can also be operated with prices from the power exchange. The possibilities to run the battery storage are depending on the local requirements.

The main benefits of this pilot are:

- Voltage support
- Integration of renewable energies
- Reduce CO_2 and Sox, NOx emissions
- Flexible storage system

Pilot 2: "Embroidered Battery"

Within the **Alpstore** project the following function and uses cases could be implemented.

- Detailed concept of "Embroidered Battery" developed
- "Embroidered Battery" developed
- Battery storage system prove functionality
- Measurements and comparison with other battery systems
- Merge both pilot activities
- Evaluation of both pilot activities realized

Beyond the general use cases the "Embroidered Battery" fulfills other technical requirements. Through the use of 3D electrodes a significant weight reduction in the electrochemical energy storage can be expected. This can lead to better battery systems with higher energy density. The main benefits are therefore:

- Construction powerful battery systems
- Rapid charging is possible
- Higher peak power can be delivered

4 Conclusions

4.1 Regional potential of the tested local options

“2nd Use Battery”

The charging of EVs can stress the local grid at places with a high amount of consumption. With a raising amount of EVs in the future, the peak loads at such places, which result from the charging, will probably increase. Therefore it is necessary to cut such peak loads by shifting the charging of the EVs or other energy consumers to reduce the impacts to location and the local grid. Beyond that decentralized production of energy with renewable sources at different locations will play an important role in the future. The production of such power plants (e.g. photovoltaic) can also have impacts for the local grid. In both ways, demand side (consumption of energy) and supply side (production of energy), the local grid may be faced with challenges, especially at hot spots (high energy consumption and production). For that reason it will be necessary to balance the supply side (e.g. photovoltaic) and the demand side (EVs). The matching of the production with photovoltaic power plants and the EV needs (charging) ensures, as much as possible, a self-consumption approach. Furthermore a sustainable mobility supply for EVs with renewable energy sources can be guaranteed.

One reason for that issue can be a stationary storage system, like battery storage, which compensate the supply and the demand side in both ways. With the pilot activity “2nd use battery” a “smart” storage was developed and implemented at the parking garage at the VKW. Therefore 2nd use batteries are used as a storage system. The prototype has proven its functionality. Because of the missing long-term experiences a larger roll out doesn’t make sense.

“Embroidered Battery”

New battery storage systems will also play an important role in the future. For that reason a new battery system based on “embroidered” electrodes was developed and realized by the University of Innsbruck. The innovative storage system was implemented, tested and evaluated by the University. Also in this case the implemented pilot was scaled on a prototype base. A bigger role out doesn’t make sense at the moment because of the missing long term experiences. It could be shown that with the use of 3D electrodes a significant weight reduction in electrochemical energy storage can be expected. This can lead to better battery systems with higher energy density.

4.2 Follow-up plans

Both systems will also be operated after the **Alpstore** project. Long-term experiences shall be gained with both of the systems. Furthermore, both systems shall be evaluated with the existing process, which was implemented in the **Alpstore** project.

4.3 Transferability to other Alpine regions

The developed pilots are both prototypes. A transfer to other Alpine regions makes it therefore difficult. Other regions can profit from the experiences what VLOTTE gained in the project.

Milan area, Italy
TEAM: TecnoCity Energy Area Manager
Case Study

Project Partner: Euroimpresa Legnano s.c.r.l.

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Case studies are contributing to AlpStore WP6

Work Package 6 Responsible: EUROIMPRESA LEGNANO s.c. a r.l.

Lead Partner: B.A.U.M. Consult, Ludwig Karg, Patrick Ansbacher, Anja Lehmann

1 Storage technologies for the ALTOMILANESE, general frame conditions and objectives

The Alto Milanese extends in the North area of the Lombardia Region, in particular into the territory of the Province of Milan. It is one of the most important and strategic area (both from the geographical and infrastructural point of views) in the north of Italy. The area represents an historical background of the Italian economic development, where the first step of the industrialization has taken place since the 19th century. Although the productive system is facing delocalization process due to the economic slump, the Alto Milanese is still characterized by a high concentration of manufacturing companies, especially in the textile and mechanic sectors. Actually, in the Alto Milanese Area (and more generally in the Lombardia region), the STATUS QUO depicts a dense populated area with pollution issues, congestions in the mobility infrastructure and more and more significant requirements of an energy model that drives to a sustainable generation portfolio both for the ecological and for the economical point of view. In order to effectively propose a (realistic) new energy model it is mandatory to correctly depict this scenario, pointing out either the energetic or the social bounds.

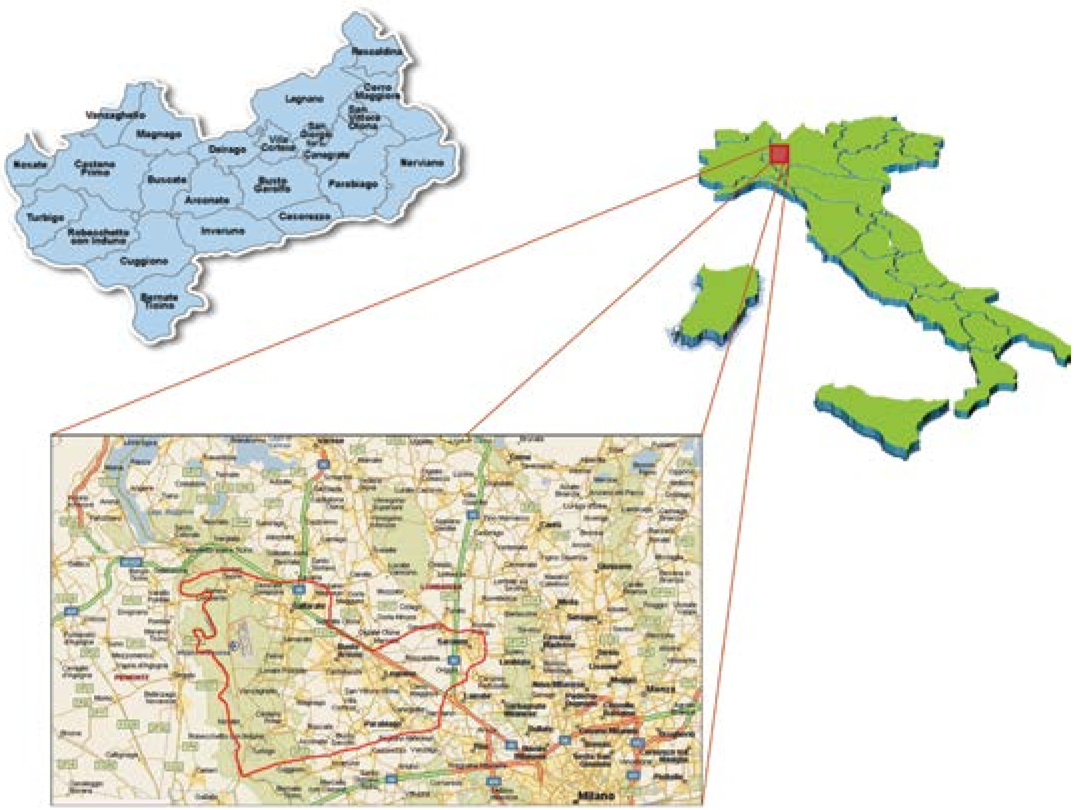

Fig. 1 Alto Milanese AREA – West Milan

Nowadays, no storage solution is already deployed in the Alto Milanese area for large scale applications. Similarly planned actions are limited to particular small scale applications, mainly for thermal purposes (e.g. Heat pump). With respect to the Gas sector, the Alto Milanese area does not have significant potential for Biogas applications, while the national legislation does not allow Power-to-Gas approach and hydrogen is considered a viable solution only in a long term scenario (looking for a costs reduction and reliability demonstration in real life applications). CAES solutions are adopted/studied for very particular small scale applications but there is no deployment/expansion program. Today it seems to be reasonable to consider this technology only for niche applications, waiting for new technologies to reach a stage of maturity. Similarly, Flywheels are studied, and in some cases tested, as an already available solution to provide "power" regulation, i.e. to provide power injections for a limited time, which actually seems to be a very limiting factor for this technology. Thermal application is limited, once again, to small scale apparatus and/or to heat pump plants. Finally, today electrochemical batteries, for stationary and mobile applications, are the only technology that has a significant application in the Alto Milanese area and in the short-medium time perspective. Nevertheless, stationary electrochemical batteries applications are today limited to energy backup apparatus and, probably due to the cost of the batteries, pilot projects/applications have not been activated in the area. In a future perspective, it is reasonable to identify a huge potential market for stationary storage applications in the Alto Milanese, due to the industrial facilities concentration and to the dense populated area. In the following chapter, more details will be provided, developing also several estimations in terms of MW/MWh that will be necessary to put in place in order to achieve the objectives in terms of RES exploitation, efficiency improvement, investment reduction in the electric grid and quality/reliability of supply. Electromobility applications already in place in the Alto Milanese area mainly regard industrial applications to handle heavy loads in industrial facilities. This kind of application is well known and consolidated. On the other hand, Electric Vehicles (EV) for people is still in an embryonic stage.

1.1 Actual and future regional energy system

Probably, nowadays the most critical topics in Alto Milanese area are: mobility congestion, pollution, and economic sustainability of the energy needs. In such a complex energy ecosystem, the electric grid is, probably, the core infrastructure, since all the main energetic processes are based on electric energy. Moreover, electric apparatus have been historically aggregated in a "grid", i.e. managed according to a more or less coordinated approach (at least in order to share one common infrastructure). Vice versa, thermal applications (based on gas and oil) are typically managed looking for an efficiency increase of the single application. Recently, electric and thermal applications are changing in a new coupled model, e.g. for the cogeneration and district heating infrastructures. It is important to point out that these applications are typically designed for the "local" thermal needs and they are connected to the grid in order to withdraw/inject the surplus/deficit of electric energy. Similarly, new users are "growing", e.g. electro mobility, looking at the electric grid as the best infrastructure useful to provide all the "energy feeding points" required. All these considerations/examples demonstrate once again the cordial role of the electric grid in the energy ecosystem, in the past, today and, even more, in the future. The Alto Milanese region is one of the most developed industrialized areas of the north of Italy and it involves a high amount of electrical energy consumption. The core of the region is the Legnano city, which is the reference for the pilot project from the industrial point of view. The power grid of the region is a network with the standard hierarchical structure typical of the UCTE system. Figure 2 shows the electric system framework of the West Milan pilot region, which could be divided into three layers: transmission system (High Voltage, HV), Medium Voltage (MV) distribution system and Low Voltage (LV) distribution system. The transmission network of the area is meshed and it is therefore structurally robust in order to manage significant power flows from the north-west to the south-east of the pilot region, without incurring in a deterioration of the power quality. The network scheme of Figure 2 includes the primary substations which represent the electrical node of the transmission system to the lower voltage levels. In particular, in each primary substation, one or more step-down transformers are located in order to connect the high voltage level (380, 220 and 132 kV) to the medium voltage system (23, 20, 15 or 10 kV). Each primary substation is equipped with two transformer machines, sized (case by case) at 16, 25 or 40 MVA. Unlike the transmission system, the MV distribution network has a radial structure system which is basically composed of small length feeders connected to the busbar of the primary substation. Furthermore, the LV system, which has the same radial structure, is connected upstream the MV level by means of the secondary substation. Because of its topology, the distribution is weaker than the transmission network and it is therefore not designed to manage bidirectional power flows and guarantee a proper power quality standard. In a scenario of higher penetration of renewables, it is important to point out that the distribution system, both MV and LV, has been designed as a passive system (i.e. without any power injection of generators). The small-medium size RES-based power plants (named Dispersed Generation, DG) are mainly connected to the distribution system and, for this reason a high penetration of these power plants may introduce new issues in the network management, affecting quality of supply. Anyway, the connection of DG at distribution level allows reducing the electrical distance between load and generation. In the past, the distribution system was totally passive and the loads connected were supplied only by generators connected at transmission level, causing a unidirectional energy flow from the HV level toward the distribution system. Nowadays, the power injections of DG occur at distribution level and they allow to locally supply loads connected at the MV and LV systems. The power flow of the system is consequently no more unidirectional and is unpredictable, as a function of the location of the resources. For this reason, lines are discharged and network losses can be improved. On the contrary, if generation is too high and, in particular, much higher than the amount of power required by loads in a portion of the distribution network, a reverse power flow along the distribution feeder may occur and the network losses may be deteriorated. In the case of low power injections, losses are improved with respect to the passive network scenario (local compensation of the load). After a certain DG power value losses increase (reverse power flow) and for higher DG power injections a deterioration with respect to the passive scenario occurs. This behavior highlights that the DG can be exploited to locally balance the load and improve the system operation in terms of losses. On the contrary, in the case of reverse power flow, the DG worsens losses. In light of the fact that the MV and LV levels have to be improved, the system of interest for the project is the distribution network. The storage system can be connected at primary substation level or it can be located close to the power plant. In the former case, the storage is a centralized application whilst, in the latter case, it represents a dispersed application. The future energy storage has to be a sustainable energy storage system which fits with the future energy scenario in terms of production sources and consumption needs. In particular, the potential for future storage applications is vast and it covers all possible services provided to the electrical system in order to enhance the penetration of RES power plants and, at the same time, the power quality of the grid. In particular, concerning the real power modulation service, the potential offered by the storage technologies is fundamental for the stability of the electrical system in a scenario of high amount of intermittent generators. Now, let's see how the primary frequency regulation of the electrical power system works. In an electrical system, in case of power mismatch between load and generation a frequency oscillation occurs; as a consequence of this, speed regulators of power plants enabled for the primary frequency control service act in order to modulate the power injection and eliminate the power imbalance. Nowadays, in Italy all power plants with size higher than 10 MW have to provide the frequency control service with the exception of power plants supplied by intermittent RES. The regulating power plants have to make available a power regulation band not lower than 1.5% of the rated power, and all the power regulation has to be provided in 30 seconds and maintained for 15 minutes. Energy Storage Systems (ESS) have a fast dynamic response (from zero to the maximum power in few seconds) and an high efficiency so they can be profitably used for the frequency control. A storage system can provide better regulation performances than thermoelectric power plants; this is an important aspect to take into account in the future scenario of strong penetration of RES which introduce an increasing randomness in term of power imbalance. A high development of intermittent power plants decreases the number of traditional power plants in service and therefore a decreasing in the power margin of the primary frequency control reserve; actually, this margin should be higher because of the high penetration of not predictable RES. Because of that, the exploitation of ESSs to increase the power margin for the primary frequency control represents a further element toward a complete integration of RES power plants into the electrical systems. The primary frequency control service provided by an integrated system of DG and ESS requires "power performances" to make energy available in a short time period (i.e. a high ratio between the power injected and the energy stored).

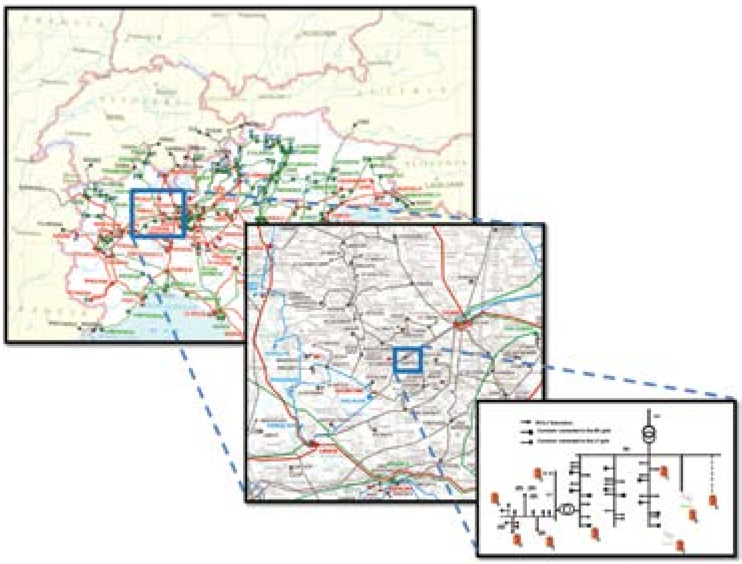

Fig. 2 Electric system framework of the West Milan

Another key application for ESSs concerns the RES production fluctuations compensation. As already introduced the energy balance has in fact to be respected in real time, acting on the injections of some flexible power plants able to accept dispatching orders from the System Operator (i.e. traditional generators). The increasing RES exploitation and the consequent rising of the production fluctuations to be compensated are causing, in order to respect the operational security margins of the system, a less cost-effective selection of the power plants called to produce the electric energy required by the system. So, in the last years, the improvement of RES dispatch capability and their better coordination with the other production and consumption system resources is taking a particular interest. In particular, as countries are today managed on the base of energy pools, i.e. on the "day ahead base", the resources (generation and consumption ones) are selected on a price based pool. Such a structure requires to predict (one day ahead) the energy production profile for each generator and, in order to have a balanced system, to respect it in real time. In order to integrate

RES generators in the pool a one day ahead prediction of their production is required (obviously the prediction will be affected by a forecast error). ESSs could allow improving the system flexibility in managing the power flows over the network, adjusting the error committed during the prediction process. In order to achieve this, it is required an ESS able to contribute to this service.

1.2 Regulatory framework

Renewable energy storage integration and electric network development are topical issues and draw the attention of all involved stakeholders. Thus, it is important to remark that the more DG penetration increases, the more imperative will be the participation of DG in the provision of ancillary services needed for a secure and reliable operation of the power system. The importance of DG involvement in the power system management is due to the fact that if DG displaces only the energy produced by central generation and not the associated flexibility and capacity, the overall cost of operate the entire system will rise. Nowadays, demand is growing from large utilities (Distribution and Transmission System Operator, DSO and TSO respectively) to exploit DG as a service for the system. In this way, generators connected along the distribution system are a resource useful to improve the stability, safety and power quality of the electric grid. They represent a regulation resource dispersed along the feeders and they can potentially offer a network control in remote points of the distribution network, normally not controlled. In fact, if well managed, DG can further improve the network operation with respect to a passive network scenario. Furthermore, the ancillary services extension to DG connected to the distribution level is essential also for a better integration of the DG itself and for increasing the hosting capacity of existing networks. By now, renewable DG technologies are, for various reasons, still relatively expensive sources of energy and moreover they tend to disrupt the normal way that power systems are operated. An incentive policy was thus necessary to promote RES expansion. This is the reason why, nowadays, these technologies are supported for environmental reasons and for the sustainability of energy security provision. In the short term, there is no doubt that DG technologies will become competitive as they are expected to become cheaper, coupled with an increasing price of fossil fuels, due to ever growing worldwide demand, especially in Asia. In this way, Grid parity will be reached, in term of cost of power plants. A distribution network ancillary service structure and an appropriate market have to be developed in line with the anticipated extension of DG as distributed energy resources for network services, thus inducing Global grid parity, including both cost of power plant and services offered for network operation and stability. Higher penetrations of DG will increase DSO options as far as network operation and planning, which could lead to lower overall costs, and set such services as an incremental revenue opportunity even for DG. The distribution system operator will become responsible for the distribution network management and the maximization of local sources dispersed in the network. In the absence of a clear policy and associated regulatory instruments on the treatment of DG, it is very unlikely that this type of generation is going to thrive. In order to foster the required changes, there is a clear need to develop and articulate appropriate rules that support the integration of DG into distribution networks. In the face of the new energy scenario, national and international technical standards have been introduced in order to define rules for the connection of active users to the electrical system. It is important to stress that provision of ancillary services from DG does not jeopardize or degrade the security of supply but should contribute to its enhancement. Nowadays, DG is in fact viewed as a disruption for the electrical system operation with little gain for the network operators. In Italy the technical standard that rules the DG connection is the CEI 0-16 (introduced in 2008) for generator connection to the MV distribution networks and the standard CEI 0-21 (introduced in 2012) which defines reference technical rules for the connection of active and passive users to the LV electrical Utilities. The Italian standard CEI 0-16 and CEI 0-21 are continuously under revision in order to include new performances. In particular, they are taking into account the content of the last Italian rule incentives and the prescriptions of the Italian transmission system operator, TERNA, and on the technical prescription for Storage Devices. Recently, Italian Energy Authority resolutions 574/2014/R/eel and 642/2014/R/eel complete the regulatory framework for ESS installations (in particular, technical standards CEI 0-16 and CEI 0-21 have been updated with respect to the new Regulatory Framework).

It is worth noticing that in such resolutions ESSs are requested (mandatory and without an economic remuneration) to provide ancillary services regulation to the main grid: such a configuration is fully compliant with the Pilot Action developed in the AlpStore project. As a matter of fact AlpStore TEAM Pilot Action is one of the first application in Italy that exploit ESSs (in a local, small scale, scale) for ancillary service regulation, resulting to be innovative and very useful as a term of reference for stakeholder, policymaker and, last but not least, technical research purpose.

2 TEAM Pilot project

The pilot application has been based on the city of Legnano, North-West of Milan city, in the business center of the Tecnocity Alto Milanese area. In particular the pilot application consists in the monitoring and control of the electric energy needs of the Tecnocity, by coordinating the power flows of the system. Technically speaking the area is connected to the main grid by two MV/LV transformers and each firm has its own meter devoted to the energy processes, moreover PV power plants, for a total 120kW rated power, are installed on the buildings roofs. Starting from this structure already in place, the pilot implementation provided the installations of new apparatus in order to achieve the project's objectives.

The pilot implementation is based on the apparatus listed below:

- a stationary Electrical Storage System
- stationary monitoring equipment (energy meters)
- energy management DEMO (VPS management tool)
- E-mobility apparatus (such as car recharge points and recharge management tool)

The key pilot objective is the realization, in the selected area, of an experimental prototype of a VPS which is able to test the energy model, considered as innovative energy solution for achieving the supply of the energy demand and provide ancillary services useful for the stability and quality of the main electrical grid.

The main stages of the implementation activity are discussed in the following.

Energy Storage System: The ESS under analysis is made up by a NaClNi high temperature battery (FIAMM-SoNick) of 23kWh capability, the total weight is about 300kg. The conversion cabinet for the connection of the battery to the Tecnocity grid contains the DC/AC system (i.e. the inverter), the filters and the protection system of the battery. The weight of this cabinet is about 500kg. The conversion system has its own control apparatus (Programmable Logic Controller, PLC) located in a dedicated box; it implements the control functions and it represents the interface with the communication system.

Measurement equipment: The implementation of the pilot project in the Tecnocity area needs measurement equipment in order to provide the status of the system useful for the VPS management tool and for the monitoring of its behavior. The measurement values, collected during the experimentation, are the electrical quantities related to each device.

Management tool of the VPS: The pilot implementation will be based on a tool for the management of the resources connected to the Tecnocity network. All the resources of the VPS have to be monitored and controlled in real time, as a virtual electric system. The VPS tool is integrated into a central computer and it has to receive the measurements collected by the measurement equipment all over the test facility (as previously described).

E-car recharge system tool: The pilot activity involves also the management of the recharge system for electric vehicles. The pilot implementation consists of installing a tool (Android APP) to manage the car recharge process. The new tool has to manage the recharge process by delivering to the user the information concerning the car charge. In particular, the feedback to the user is a simple "traffic light" that will clearly depict if the involved area has, in that particular moment, a surplus of production (green light, i.e. it results to be an ideal time slot in order to charge the car), a deficit (red line) or an intermediate status (yellow light). Actually, this information depends on the status of the network, the loads, and the availability of the energy sources.

Finally, the aim of the pilot implementation is to evaluate the feasibility of the proposed methodology in a real small-scale application. After the installation of the apparatus within the test facility, a monitoring process has been launched in order to verify:

- the effectiveness of the energy model in describing the energy behavior of the area;
- the capability of the VPS tool in satisfying the energy needs of the area by exploiting the resources available (such as the PV plant and the ESS);
- the capability of the VPS tool to offer ancillary services for the electrical system by ESS;
- the effectiveness of an e-car recharge tool linked to RES.

The above mentioned aspects represent the expected outputs of the pilot implementation. The obtained results can be extended to the Alto Milanese area, at region level, but also in a wider context, at National or European level.

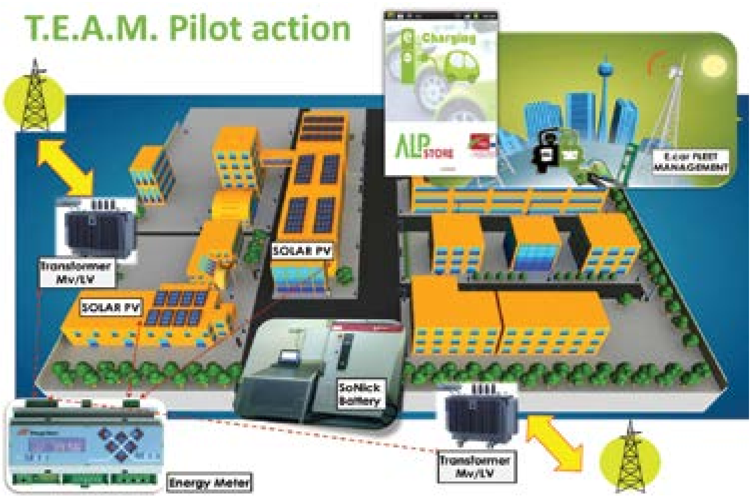

Fig. 3 TEAM pilot action at a glance

2.1 Characteristics of the field test

The TEAM pilot application has been built up in the city of Legnano. Euroimpresa Legnano will develop a demonstrative action which is useful to better clarify the approach proposed in the **Alpstore** application form, applying it on the business center of the Tecnocity Alto Milanese area. The Technocity area is comprosed by several subareas, business entities, for an overall area of more than 25000 m2. It counts a total of about 500 employees. In particular, Tecnocity Alto Milanese is hosting:

- 54 service and production companies with high innovative and technological skills;
- 10 firms that are daily receiving assistance both in start-up and development phases (business consolidation and access to public funding);
- 8 laboratories which support local companies in product and process certifications, in line with European legislation.

Concerning energy aspects, Tecnocity area is connected to the main grid by two medium voltage/ low voltage transformers that feed the lighting and thermal apparatus. Each firm has its own meter devoted to energy processes. The Tecnocity area had been selected as object of the TEAM pilot action thanks to its peculiarities. First of all, companies and laboratories within the Tecnocity, sharing some services and facilities, are saving costs and optimizing the efficiency of these activities. This allows the area to be well suited for the **Alpstore** experimentation, which is oriented at improving the efficiency of the energy system. Moreover, the Tecnocity area is big enough to locate the apparatus of the project, which has a large dimension, such as the battery system and the measurement equipment. Secondly, the area is already using RESs, thanks to 2 PV power plants. Furthermore, since Tecnocity is a business area, the TEAM pilot action will be oriented to represent a model in order to convert other industrial areas located in the Region. The territory Alto Milanese is, indeed, characterized by the presence of several disused industrial area which needed to be revitalize, also on the energy side. Therefore, the Tecnocity can represent a clear example of recovery of industrial areas for the territory of Legnano and, in large-scale, for the West Milan area. In addition, Tecnocity has strong relationships with administrative authorities and the industrial sector; Tecnocity's visibility will be well exploited in order to have an effective dissemination of the **AlpStore** project. In conclusion, the area is a good example of small-scale model to apply the concept of Virtual Power System (VPS) and to carry out experimental and validation tests related to the project.

2.2 Storage technologies and frame conditions

In principle, all services provided by storage entails an energy time shift from the charging time to the discharging time of the energy previously stored. ESSs are mainly exploited to ensure a better integration of RESs. That's because it is not possible to perfectly cover in real time the power demand by the intermittent and not predictable energy produced by RESs. For example, the intermittent source can be compensated in order to achieve a regular and predictable generation profile. A more regular profile would reduce the power modulation of traditional power plants which would otherwise have to compensate the entire fluctuation of the RESs production. In this application the ESS manages electrical energy and it is an integral part of the electrical system. The ESS which fits for this task is clearly the renewable based storage system that can store and deliver the sun's energy almost in real time. With respect to the electric grid point of view, the ESS can be a centralized application or a dispersed one. In the former case big size storages (tens of MW) are located in few strategic points of the electrical transmission system (i.e. in the high voltage system). In the latter application, a lot of small size storage systems (up to 1 MW) are dispersed along the distribution network (both medium voltage and low voltage system). In the dispersed application, the storage is usually located near the renewable generator and they form a unique power plant. The use of ESSs to encourage the renewable plants penetration is a dispersed usage of this technology. In fact, in a forward-looking perspective, they will be integrated in each DG and therefore they will offer an alternative to the centralized storage systems. Actually, to introduce the changing scenario we are experiencing today it is necessary to briefly describe the evolution of the renewable power plants in the current electrical system. As well known, by means of the DG (Dispersed Generation) it is possible to exploit RESs spread on the territory and reducing the use of fossil fuels. Nowadays, DG is integrating into the electrical system according to a "fit and forget" approach; since the current distribution network is designed as a passive systems (i.e. not able to receive high amount of generated power) high DG power injections may affect the quality of supply and the system stability. As the DG penetration increases it will become a technical and economic imperative that DG participates in the provision of ancillary services needed for a secure and reliable operation of the power system. This is important for the simple reason that if DG only displaces the energy produced by central generation but not the associated flexibility and capacity, the overall cost of operating the entire system will rise. The new scenario implies new rules for the active users connected to the distribution network. Until now, DG power plants don't offer any ancillary service[1] for the network operation. Nowadays, demand is growing from large utilities to exploit DG as a service for the system. In this way generators connected along the distribution system are an ancillary service resource which is useful, but even necessary, to improve the stability, safety and power quality of the electric grid. They represent a regulation resources dispersed along the feeders and they can potentially offer a network control in remote points of the distribution network normally not controlled. Furthermore, the ancillary services extension to DG connected to the distribution level is essential also for a better integration of the DG itself and for an increasing of the hosting capacity of existing networks. These services involve both the transmission and the distribution system management. Due to the intermittence of the renewable resource, a wide set of ancillary services can be guaranteed only if the DG is coupled with a suitable ESS. In this case, the ESS is integrated with the DG unit, i.e. a generation and control dispersed resource for both the production of energy and the provision of ancillary services. When installed in the grid, in a given instant a battery must provide a power exchange (injection/withdrawal) that depends on both the service to which the ESS is devoted and the site of connection inside the network (technical constraints). The response times and the length of time required depends on the service performed: in fact, different applications may require different autonomies, varying between few seconds and several hours. If an exchange of large power quantities is needed in short time intervals (from fractions of a second to some tenths of seconds), the ESS must cover a proper "power" performances; on the contrary, if it is necessary to absorb/inject energy for long time period (minutes or even hours) with power close to the rated value, an "energy" performance is required. Power performances technologies are super capacitors and flywheels, which can supply useful ancillary services to the network, especially for power quality and primary frequency regulation. ESSs technologies with interesting "energy" performances are, besides pumped-hydro and CAES plants, some electrochemical ESSs, such as lithium-ion, sodium-sulphur or redox flow batteries. This classification in terms of time performances strongly

[1] Ancillary Services could be defined as all the regulation actions to be put in place in order to have and efficient and reliable operation of the electric system. In a more general definition, ancillary service is anything that supports the transmission of electricity from its generation site to the customer. Services may include load regulation, spinning reserve, non-spinning reserve, replacement reserve and voltage support.

impacts on the sizing of the equipment and therefore on the price of the storage itself. As the cost of ESSs is mainly related to their autonomy (energy), this is one of the aspects most limiting the ESSs spreading in power systems. These ESS's technologies can perform multiple functions to support the network, such as peak-shaving and time-shifting. While pumped-hydro and CAES plants have typically large sizes, with power usually of some megawatts and capacity of some hours, which makes them particularly adapt for transmission networks, electrochemical ESSs, thanks to their modularity, can provide their support even to distribution grids, if integrated with power plants. The pilot action, beside, point out how the ESS solutions are quite unknown (till not regulated) in terms of health requirements and insurance bounds. Different technologies imply different "risks", nevertheless the topic is almost unknown for insurance companies, affecting the viability of a large scale deployment, or, equivalently, demonstrating the "young" nature of these applications.

2.3 Research design and schedule

Nowadays, the level of DG in the electrical system is quite high and it is connected to the system with a *fit and forget* approach, furthermore, the DG is going to reach the functional penetration limit which may compromise the electrical system stability and security. RESs inject to the network the power available which is intermittent depending on the weather and energy conditions (e.g. hydraulic flow, primary energy source availability, etc.). First feedbacks of the Italian authorities on the matter are the Italian technical standards CEI EN 0-16 and CEI EN 0-21. These standards introduce new rules for the connection of the RESs plants to the existing grid, and, recently, define also the rules for ESS. One of main objectives of the future energetic framework is the possibility to manage at system level the power flows produced by the DG. In order to face this scenario one possible solution is to develop energy storage technologies for the regulation of the power flows; furthermore, systems of monitoring and control based on computation and communication apparatus have to be developed. By interacting with the entire system it is possible to coordinate the status of the grid, of the sources and storage systems, in order to satisfy the production and management objectives and guaranteeing the services required for a correct network operation. The storage system has to be designed in terms of both power capability and energy capability according to the kind of service offered by the apparatus. For example, for the time shifting service the energy is absorbed in the period of higher production and in general it is modulated to meet the required power profile; for this service a system with energy performances is required. On the contrary, for services of network stabilization and compensation of the power oscillations from renewables, a storage system with power performances is necessary. The proposed scheme for the general description of the energy model under analysis is composed by the storage system and the dispersed generators, as shown below. It considers the electric variables as the primary variables of the system. The framework depicts the main components of the structure, the connection between them and the connection with the distribution system through the Point of Common Coupling (PCC).

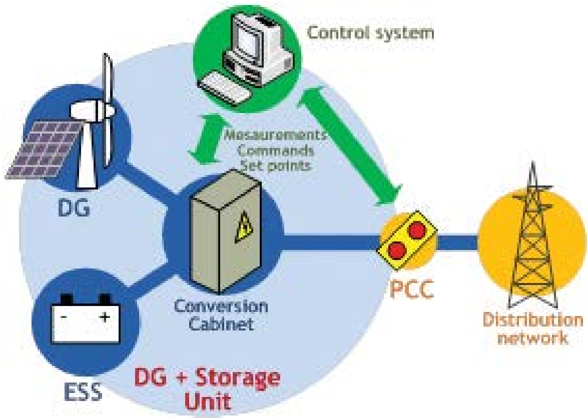

Fig. 4   General scheme of dispersed generation unit integrated with storage system

With the growing of the energy production from RESs, the MV and LV distribution network are affected by bidirectional power flows caused by DG. The higher is the level of DG penetration, the higher is the probability of raising new issues concerning the management and planning of the electrical system; i.e. higher cost for the system operator. The main costs are:

- adequacy costs, a certain amount of capacity of traditional power plants is necessary to guarantee to cover the power demand in real time and mainly during the peak condition,
- unbalanced costs, with an high penetration of intermittent generation an higher flexibility for the rest of the system is necessary to achieve the power balance and the network stability;
- costs for the network reinforcement in order to host new RESs plants to the electrical system.

The current network structure can be adopted only till the DG level is kept below some limits. In fact, in some weak area of the distribution system the energy injections may cause a reverse power flow along the distribution feeder and over-voltages in some busses. It means that the system is not able to host all the power injected by the renewable sources. If the voltage value is not in compliance with the protection thresholds, the generator can be disconnected from the system with a power curtailment in some time intervals and risk of system instability. If DG penetration increases over some limits it is necessary to modify the electrical system in terms of control/management or even, more drastically, in terms of network structure. The easiest technical solution for the control of the system with high DG penetration is to integrate the intermittent power generators with storage systems in order to compensate the power oscillations due to the uncertainty of the primary sources. This is a short-medium period solution and it represents the first implementation model of the master plan previously discussed. It is a centralized approach of implementation of storage technologies into the system; because of the centralized characteristic of this configuration, the transmission and distribution system operators are in charge of the operation and management of the storage. For example, in Italy some pilot project concerning stationary storage applications have been experimented in the high voltage system. A strategy is represented by connecting a storage system to the Primary Substation (PS) of a distribution system with high penetration DG. The storage is directly controlled by the Distribution System Operator (DSO). In this configuration the PS includes systems for the energy production forecasting, sensors for the monitoring of the electrical network parameters, communication with the producers for the regulation of the power flow in the network, a storage system for the power modulation and point for the charge of electric vehicles.

Fig. 5 Configuration of the local electrical system in the current scenario

Fig. 6 Configuration of the electrical system in the future scenario with centralized energy storage and electric cars

The operator of the network manages the set-point of the storage system on the base of the forecasting and planning of the resources, and, if necessary, it coordinates the operation of its traditional power plants. Operator needs a communication infrastructure to monitor in real time the portion of the system connected to the PS and involved in the control of the centralized storage. Furthermore, it requires an acquisition system of the network data and a real time algorithm for the state estimation of the system and the computation of the optimum storage set-points. This framework requires a communication infrastructure and a strong computation capability. In addition, the centralized storage system requires high initial costs to build the communication and data infrastructure and to design and build the storage system with a suitable size and the annexed apparatus. Beside the central storage management implemented in the PS, a second option could be to integrate the ESS in the DG power plant by realizing a dispersed storage configuration as shown below. As for the centralized energy storage configuration, this configuration represents the second short-medium period implementation model of storage systems. The delocalization framework implies an involvement of a lot of final users; it impacts more subjects than the centralized solutions. Each DG power plant has a proper control system for the definition of the power set-point of the ESS based in the local measurements. The storage system can be exploited to achieve one of the following functions:

- optimization of the energy produced by the primary source,
- smoothing of the generation profile to avoid unbalanced costs,
- primary frequency control and voltage control,
- modulation of the energy production to meet the dispatching program with the DSO,
- feeding of the local loads in case of disconnection from the main system (islanding operation).

This solution can be achieved by providing incentives to the users that offers these services. According to this strategy each power plant operates locally without requiring a communication infrastructure, the DSO can manage the portion of the system by communicating a reference operation point to the producer exceptionally. This configuration can be implemented only if an incentive market is established in order to remunerate the ancillary services provided by the local storage to the electrical system.

Fig. 7 Configuration of the electrical system in the future scenario with dispersed energy storage with local control and electric cars

In case of higher penetration of intermittent sources, an evolution of the electrical system is necessary. In particular, the integration of a fast and reliable communication infrastructure all along the network allows controlling the power flows of the grid. The evolution of the logical scheme will allow to remotely controlling the dispersed ESSs, as depicted in the figure 8: This configuration allows achieving a real time interaction between the system operator and each power plant in order to remotely control them for the implementation of different functions and services. In particular, the DSO can monitor in real time the power plant production and send the proper set-point signals;

in addition, it is possible to inform the users with signals about their consumption, to manage the energy costs and to increase the performances of the energy profile thanks to the continuous information exchange with the system operator and also web services.

Fig. 8 Configuration of the electrical system in the future scenario with dispersed energy storage with external control and electric cars

In such an evolving frame, the Pilot action is based on a new energy planning procedure, in which, exploiting a bottom-up approach, the goal is to design the energy portfolio from the “local” scale perspective, exploiting the “local” resource available on the site into analysis. Nevertheless, the “global” scale problem has to be taken into account evaluating the whole energy ecosystem in terms of economical sustainability, security of supply, quality of supply. Consequently, the planning methodology proposed could not be taken as a single application but has to be coordinated with the energy market rules and with the technical resolutions adopted in order to guarantee the “stability” of the energy system (over a national and international scale). Actually, the approach proposed could be divided in two phases: the first consists of an energy planning procedure at local level (with the aims to select the energy resources that better fit with the local needs), while the second aims to effectively integrate the local “cell” in the national energy system (e.g. adopting storage apparatus in order to provide “regulations” and guarantee the security/quality of supply). In particular, the vision of the proposed methodology is to develop a planning program of the energy sources available according to the needs of the pilot region, i.e. to develop an energy model able to match the energy needs of an area with the resource locally available. In order to define the planning program, the methodology analyses the energy flows of a portion of the electrical network and it computes the suitable amount of the production sources available. The procedure focuses on a portion of the electrical system and it considers the energy needs of this portion. At this point it is necessary to identify a point of the system which represents the equivalent energy point of the region. In particular, the example described in the following considers the Primary Substation (PS) of the electric network as a significant point of an area: the power flow measured at this point represents the energy needs of the area and therefore the energy behavior of the region under study. The methodology is based on the analysis of the energy behavior of the identified area. The study consists of the analysis of the energy flow at the PS level which is usually described by a chronological vector data (e.g. the measurements samples of a one year timeline). The chronological data can be represented in different forms; one of the simplest ways is the so called energy map. Beside the energy map of the load demand of the region, in order to define the energy planning of the area it is necessary to introduce the energy maps of the available sources, one for each typology.

After the identification of the area, the production profile of each resource inside the area has to be collected. It indicates the behavior of that particular source inside the detected region. After the definition of the energy maps of each production source typology, a compatibility analysis between the PS consumption and the sources production is carried out. It implies the verification of the capability of each potential available resource in supplying the local load: basically this procedure phase consists in superimposing the energy map of the consumption with the energy map of each of the sources and verifying, according to particular algorithms, how much close is the production profile with the consumption profile of the area. It includes a screening procedure for the definition of proper indices for evaluating if a source fits with the profile of the energy map at the PS. The output of this procedure is a ranking of the sources organized according to their capability in satisfying the consumption needs. The inputs of the methodology are the energy map of the PS and the energy maps of each energy source, ranked according to the matching procedure previously discussed. The output is the maximum power which is possible to install for each source topology and that satisfy at the same time the target function. These values represent the input for the master plan of the selected area. The installation of a certain amount of power in the area feeds the load of the region and therefore it change the power flow at the PS: the energy map at the PS will be modified. The target function adopted in this methodology is to compensate the load by the local production and in particular to achieve a reverse power flow hours/year in compliance with the Italian technical requirements (less than 5%, defined with the goal to keep the “load” nature of the PS, i.e. to guarantee the security of supply). In addition, both the electric vehicles recharging systems and the storage can be integrated into the network for a further improvement of the system operation. The electric vehicles represent a controllable load and therefore they are a source which can be exploited to enhance the energy map at the PS level; Figure 9 shows an application of the electric vehicles in a short-medium timeline: they can be exploited to further improve the new energy map obtained after the planning of the production sources. In particular, the car’s charging has to occur in the scenario of low power consumption, i.e. in the blue time steps of the PS energy map. The energy map at the PS can be also exploited to compute the maximum capacity of the network to host electric vehicles; in detail the theoretical maximum power required by the recharge system is the margin between the peak of consumption of the energy map and the maximum power capacity of the network. On the contrary, in the short-medium time scenario the storage system is integrated into the system not for the improvement of the energy map of the PS but in order to provide services to achieve the global system needs such as the system stability.

Applying the planning procedure to the Pilot Area (Legnano City) the optimal solution identified results in new installation for 11.6 MW of photovoltaic power plant and 3.7 MW of cogeneration (district heating) generators. Such new resource will be able to cut the energy needs of the city by 45%. Moreover, coupling it with storage solution devoted to the primary frequency and voltage control, sized at about 500 kW on nominal power and 500 kWh of nominal capacity (i.e. ESS is assumed to contribute to the ancillary services “in place of / supporting” the PV generators), the new scenario could be effective in terms of quality and reliability of the energy supply.

In the Pilot action, an ESS has been developed and experimentally tested in order to check

and validate the feasibility of exploiting a small scale ESS for the ancillary services management (figure 10). The experimental application resulted in a success, nevertheless the heavy use of the apparatus for such a challenging regulation drive to an estimation useful life of the storage lower than 4-5 years. Consequently, adequate incentive scheme has to be introduced in the regulatory framework in order to make such an approach profitable/ sustainable.

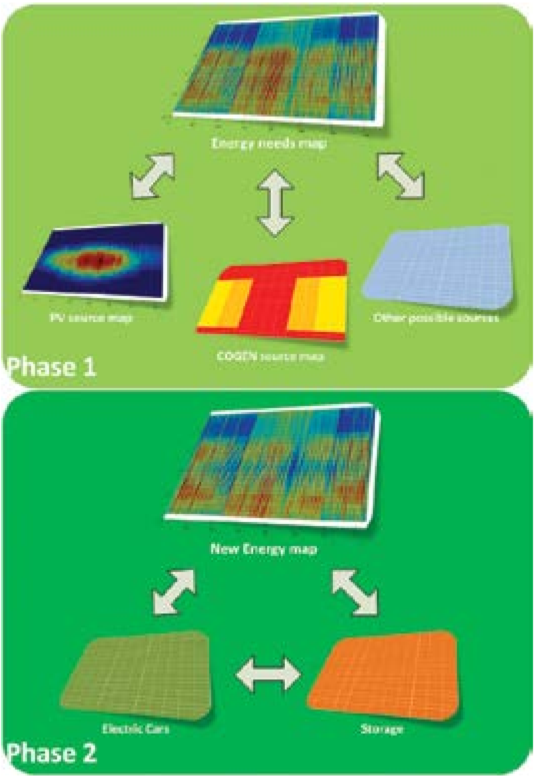

Fig. 9 Energy maps in the planning definition

Fig. 10 ESS prototype experimentally tested in the Pilot action

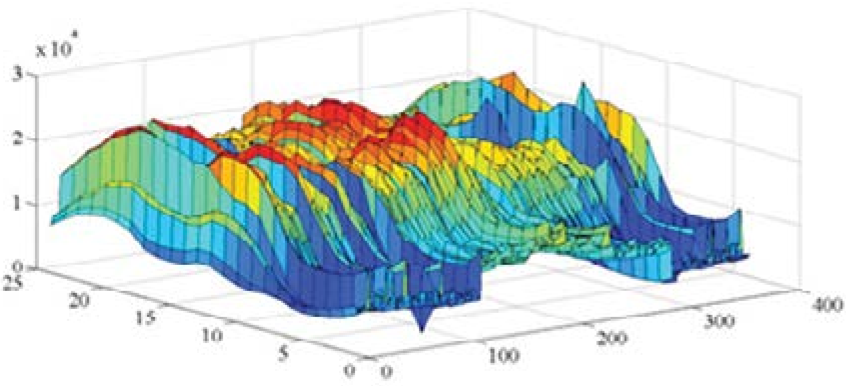

Fig. 11 Today's load energy map of the city of Lengnano (real data)

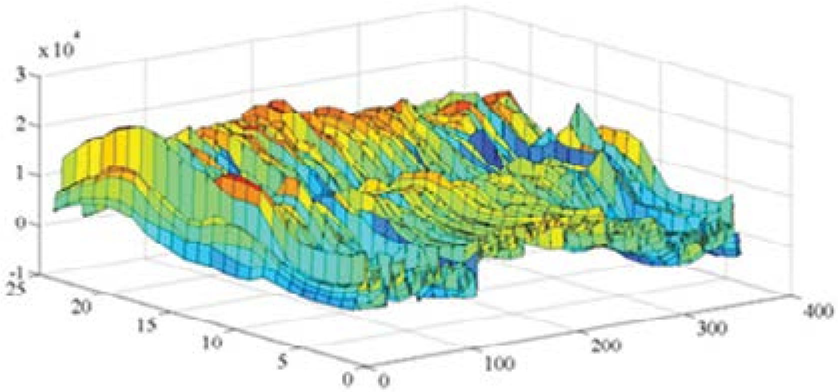

Fig. 12 Load energy map for the city of Legnano out of the contributions of the best generation profile mix

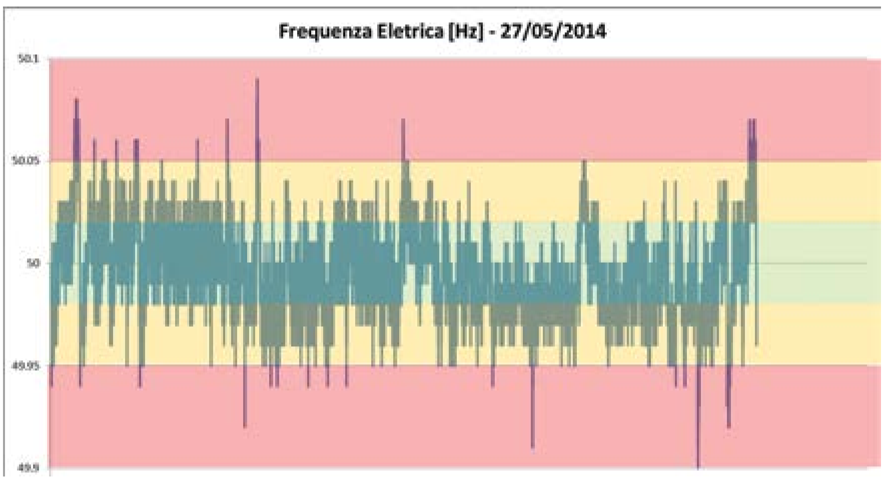

Fig. 13 Frequency sampled in the experimental test in Tecnocity ([Hz] vs time, one day time window)

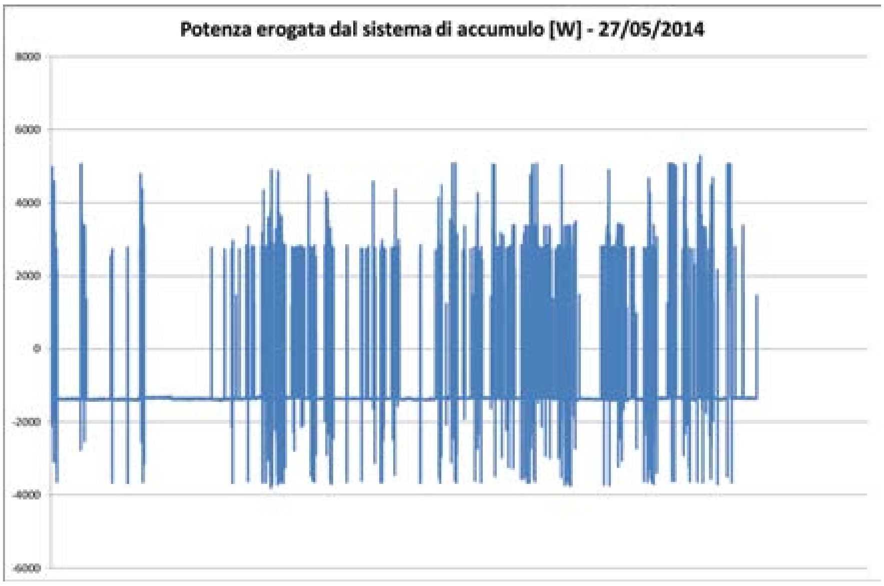

Fig. 14 Power flows of the ESS apparatus in the experimental test in Tecnocity ([W] vs time, one day time window)

Figure 11 reports the real life samples of the Legnano city energy need over a whole year, while figure 12 details the energy behavior achievable thanks to the optimal energy mix calculated with the energy planning procedure proposed. It is relevant to point out how the procedure identify Solar production as the resource that better fit with the consumption of the area and calculate the maximum renewable production that could be deployed with respect to the “security” bounds of the grid (11.6 MW). Moreover, it is important to point out how the “optimized” energy portfolio drives to a more “flat” energy maps, i.e. to a reduced stress on the electric system. Finally, in order to correctly contribute to the regulation services, a small scale ESS has been installed in the Tecnocity area in order to contribute to the frequency regulation service, supporting the already in place 120 kW PV generators. Figure 13 depicts the frequency samples recorded in a defined day (27/05/2014). The yellow area of the picture correspond to frequency samples really close to the nominal value (50 [Hz]), i.e. to a situation in which the energy balance is well respected; whilst the pink area correspond to situation in which loads exceed consumptions, i.e. the frequency resulted to be too low, and vice-versa. In these situation, ESSs should be asked to contribute to support the energy balance in order to guarantee the quality and security of supply (figure 14 refers to the energy flows recorded, in the same day, on the ESS prototype installed in Tecnocity).

2.4 Implementation process

The description of the tasks of the implementation plan is here given in terms of actions made or device installed, according to the “as build” Gantt time-plan reported in table 1.

Table 1: "As built" Gantt scheme of the Pilot Action

	nov-13	dec 13	jan 14	feb-14	mar-14	apr-14	May 14	jun 14	jul 14	ag 14	sept 14	oct 14	nov-14	dic-14	gen-15	feb-15
Communication plan for the pilot action																
Events and technical meetings Communication tools and materials	■					■			■				■			■
Electrical Storage System (ESS)																
Choice of the location and placement of the Stationary ESS			■	■	■	■										
Metering and VPS control system																
Set-up of the measurement equipment and verification of the measurement values of the electrical quantities related to each device				■	■	■	■	■	■	■	■	■	■			
Stationary monitoring equipment 1/2 (grid-front meters): installation and verification of the behavior of each device of the system in response to an external signal.				■	■	■	■	■	■	■	■	■	■	■		
Stationary monitoring equipment 2/2 (controlling apparatus, such as VPS management tool): implentation and verifical of the VPS tool necessary to coordinate the ESS, the PV and the load in order to satisfy the anergetic needs of the area and to provide the ancillary services to the main grid					■	■	■	■	■	■	■	■	■	■		
Communication system																
Verification of the communication system between the VPS tool and each device					■								■	■		
E-car recharge system tool																
Installation of the E-mobility apparatus (car recharge points and recharge management tool), availability of the Android application for smart phone and verification of the YES/NO signal of possible charge to the end user						■	■	■	■							
Data gathering, analysis and numerical simulations																
Knowledge management system for the collection and analysis of data and test of the Energy Model.					■	■	■	■	■	■	■	■	■	■	■	■

In the first phase, the **Storage apparatus** has been installed and tested. Actually, the storage apparatus operated without requiring coordination with other apparatus (i.e. it locally measures the electric voltage and frequency and contributes to the grid regulations).

In the second phase, a **VPS infrastructure** has been installed in order to monitor the energy flows of the area and validate the energy model proposed. Unfortunately, several technical and administrative problems caused a delay in the full operation of the system. Consequently, the energy monitoring infrastructure has been completed only in February 2015. Nevertheless the delay has not caused criticalities in the Pilot action because the monitoring infrastructure has been designed for the demonstration of the Energy Model proposed, and it is linked with the web-demo public internet site (http://62.149.217.122/AlpStore/).

The **E-mobility apparatus** (car recharge points and recharge management tool) has been installed, also providing an Android application for smart phone. The Android APP provides information to the final user about the "best" behavior in recharging the e.cars.

Finally, **Data gathering, analysis** and **numerical simulation**; data have been gathered in real time, stored and collected in order to test the Energy Model proposed; numerical simulation have been carried out in order to extend the data collected in the "small scale" pilot application to a "realistic" large scale. The numerical studies are available on the public web-demo site (http://62.149.217.122/AlpStore/).

2.5 Scenarios / simulations

As already stated, RESs are a key driver for a new, sustainable, energy ecosystem. Nevertheless, RESs introduce some drawbacks in the operation of electric networks, which must be properly addressed in order to avoid deteriorating power quality, reliability and supply efficiency. In particular, one of the main RESs issues is their unpredictability, which reduces the programmability of the energy flows on networks. The energy balance between load and generation has to be respected in real time, acting on the injections of some flexible power plants able to accept dispatching orders from the System Operator (i.e. conventional generators). Increasing cost in the selection of conventional power plants is being caused by the rising RES exploitation and the consequent production fluctuations, in order to respect the operational security margins of the system. In fact, in the past, (cheap) base load power plants (e.g., coal, fuel oil, etc.) could satisfy most of national load requirements, thanks to the small daily/seasonal variability of the load profile; in addition, being the energy consumption easily predictable, only a small amount of dispatching resources needed to be collected from (expensive) peaking power plants (e.g., natural gas, hydro, etc.). Today, the situation is substantially different: the increased variability of load profiles, often incompatible with the operating constraints of base load power plants, together with the need to compensate in real time RESs fluctuations, caused a rising exploitation of peaking power plants. Consequently, in the last few years, the improvement in dispatch capability of RES and their better coordination with the other production (and consumption) resources is of increasing interest. Presently, in the liberalized markets (e.g., in Italy, Germany, Spain and UK), if RESs plants do not meet the submitted schedule for output power, they face financial penalties. In Italy, if mismatches between actual and scheduled production exceed the given tolerance, the energy injections out of the tolerance band are charged of imbalance penalties, with an approach similar to that applied to conventional generators. However, on the contrary of conventional power plants, which can be dispatched conveniently to meet the submitted schedule, non-programmable RESs generators cannot avoid penalties. The unique way the user has to prevent undesirable imbalance costs is to adopt suitable expedients to make the RES power plant programmable. In order to achieve such a challenging target, ESS is one of the most promising options. Consequently, numerical simulation has been developed in order to evaluate, also exploiting data collected in the Pilot action, if the ESS application could be market effective in managing imbalance costs. In particular, in this section, a study of the economic feasibility of the solution based on the ESS is discussed, supposing it to be coupled with a PV power plant (i.e. numeral analysis refer to a configuration similar to the one of the Pilot action: 100 kW PV power plant locally coupled with an ESS). A cost/benefit analysis is performed in order to identify the best trade-off between the cost required for the ESS and its benefits for the user. The costs involved are the investment costs of the ESS (CAPEX) and the price of the energy lost during the charge/discharge cycles (OPEX). For simplicity, the maintenance costs of the ESS are assumed already included in the initial cost of investment and unrelated to the lifespan of the storage apparatus. The benefits of the ESS regulation are evaluated in terms of reduction of the yearly PV production subject to imbalance fees. All the quantities involved in the analysis (imbalances, losses, charge/discharge cycles) are evaluated as a function of the PV production by time-dependent simulations carried out on the data collected in the Pilot Action. The cost/benefit analysis is carried out according to the assumptions described in the following. The penalties for imbalance are evaluated with the same approach adopted in the Italian regulatory framework. RES plants must declare the production program a day in advance. On the basis of this program and of the energy price on the Day-Ahead Market, the RES plant is remunerated. However, the average measured production of the DG plant can be different with respect to the programmed one. If the gap between the average measured PV production and the forecasted value, assessed on an hourly basis, exceeds the admitted tolerance, an imbalance penalty is applied to the amount of energy exceeding the tolerance limit. The CAPEX costs are evaluated as a combination of the costs of the ESS per unit, respectively, of Storage Rated Capacity (SRC) and Storage Rated Power (SRP). Moreover, the OPEX of the ESS investment are assumed proportional to the energy lost during the charge/discharge cycle and a discount rate (DR) of 8% is introduced. As already mentioned, the overall efficiency of the ESS (inverter + batteries) is considered equal to 90%. According to the cost of the storage technology and the amount of imbalance penalties previously evaluated, the Benefit/Cost Ratio (BCR) of the investment has been calculated. Finally, three weather forecasting methodologies (FM) have been developed and tested: the Persistence Model, weather forecasts applied to a simple linear regression model of the PV power plant (LRWF model), weather forecasts applied to a PV power plant model based on a neural network (NNWF model). The goal of this first step is not to build up an innovative FM; the target is to collect realistic data (FMs implemented on medium-small size PV plants) for the following ESS design procedure. The results obtained with the simulations depict that, under the assumptions of the study, the ESS becomes an effective solution to reduce RES imbalances with costs per unit of SRC lower than 107 €/kWh with the Persistence Model, 160 €/kWh with the LRWF model and 154 €/kWh with the NNWF model. The situation changes considerably at an increase in the imbalance penalties, the break-even cost of the ESS increases with all the three FMs proposed: respectively, 200, 289 and 286 €/kWh. This is an important fact considering that in the future, with an increase in the share of RESs, the costs required to ensure the real-time balance of the power system are expected to increase (proportionately with the imbalance penalties applied to RES plants. Nevertheless, for the feasibility of the investment a significant reduction in the cost of the storage technologies with respect to today's scenario is pivotal. The results about the ESS sizing, in energy capacity and power, provide other useful indications. It is important to point out that, in addition to the cost of the storage technology and the value of imbalance penalties, in perspective other factors will contribute to make more affordable the adoption of ESSs for a better RES programmability. In particular, the increasing of the charge/discharge cycles that the ESS can perform during its life has a direct effect on the investment feasibility (especially for small sized ESSs, which usually carry out more charge/discharge cycles and have a shorter service life).

In the project, the possibility of achieving a fully-programmable production profile for a PV power plant has been assessed. In particular, the study focuses on the evaluation of the technical and economic feasibility of using ESSs to avoid unbalances (penalties) in the electricity market PV management. The numerical analysis point out that for such an application ESSs (performing at the best of nowadays technological limit) should have to be "on the shelf" with economic costs ranging from 107 to 289 €/MWh. Comparing this figure with the commercial costs they have today (500-800 €/MWh) it could be concluded that in the short/medium term ESS could be effective if their cost will be reduced to one third.

2.6 Technical Findings

The TEAM Pilot action demonstrate the effectiveness of a new, RES based, effective energy planning in which storage apparatus has a key role in order to guarantee the quality and security of supply. In such a model, electromobility is a new actor, quite interesting to the possibility to manage the consumption (charging processes) with respect to the area requirements. Moreover, experimental application has been developed in order to test and validate the viability of ESS exploitation for the ancillary services contribution.

As a general conclusion it could be stated that storage solution and electromobility are technically ready for a large scale deployment, and in the mid-term scenario such solution will cover the role of the enabling technology of the new (RES based) energy ecosystem; nevertheless, today, economic costs have to be carefully evaluated. Moreover, technical management of ESS and e.mobility is a complex topic, it is important to state that only rigorous studies could bring significant results.

Detailed description of the technical analysis, simulations, and experimental application developed in the **AlpStore** project can be found in:

- *Delfanti, M., Falabretti, D. , Merlo, M. "Energy storage for PV power plant dispatching", Renewable Energy, Volume 80, August 01, 2015, Pages 61-72*
- *Benetti, G., Delfanti, M., Facchinetti, T., Falabretti, D., Merlo, M. "Real-Time Modeling and Control of Electric Vehicles Charging Processes", IEEE Transactions on Smart Grid (article in press)*
- *Delfanti, M., Falabretti, D., Merlo, M., Monfredini, G., Pandolfi, L. "AlpStore project: A viable model for renewables exploitation in the Alps", Energy Procedia, Volume 46, 2014, Pages 3-12*
- *Delfanti, M. , Falabretti, D., Merlo, M. , Monfredini, G. "Distributed generation integration in the electric grid: Energy storage system for frequency control", Journal of Applied Mathematics, Volume 2014, 2014, Article number 198427*

2.7 Economic effects

Generation capacity of renewables, led by solar PV and wind power, is rising across the globe, consequently large and small investors are very active to find cost-effective means to store power and balance energy systems. Actually there are many different energy storage technologies in various stages of development; nevertheless so far there is not a market and cost-benefit rationale to drive growth in energy storage. State financing, subsidies, tax credits and regulatory measures are today pivotal to the equation, both for small and large scale storage. The results of the Pilot Action confirm these assumptions.

But, experts all over the world agree that "The fact is that every country into renewables is going to need storage capacity, sooner or later, as the volume of weather-dependent renewables increase in the energy mixes". Storage market in Europe has reached an "early commercial stage" and will grow faster and faster in the future thanks to the consolidation of regulatory frameworks (market researchers estimate that the distributed storage market worldwide will grow from about 100 MW today to 1000 MW by 2020). In such a scenario, for the densely populated and industrialized area of the Alto Milanese relevant benefits are expected either on the quality of life (thanks to a better exploitation of RESs and on a pollution free mobility) and on the commercial development based on the energy storage industry.

2.8 Environmental impact & Social benefits

The socioeconomic, environmental, political and territorial needs depict the energy scenario of the future in which it is necessary to introduce a new paradigm of the energy system. From the energy production point of view it is necessary to maximize the energy amount available by RESs by integrating this new form of generation with the traditional power plants. At network side, it is necessary to upgrade the distribution system in order to allow the Dispersed Generation (DG) spread along the system. At the utilization side it is necessary to introduce a smart and rational energy consumption which faces both the user needs and the needs of all other stakeholders involved with the aim of energy saving and sustainability. Actually, **AlpStore** propose a new Energetic model aimed to apply RESs based energy ecosystems in built-up urban districts; the project's mission is also to establish a social system which can be sustainably developed in an already established city, by bringing together companies' technologies (almost at the level of practical use) in Alto Milanese. In order to achieve the above described mission, the model has been designed following four elements: be "scalable," achieve "speedy" development, be "sophisticated" (sensible) and give "satisfaction" to people. In particular, the project aims to create a new Energy Model which gives satisfaction to its users. It provides solutions where the citizens of the area participate and achieve ecological living without compromising convenience and without imposing restraints. With respect to the model proposed, citizens receive information, information about their energy behavior (thanks to energy meters), information about the energy flows of the area in which they live, information about the best RESs (i.e. the one that better fit with their energy needs), information about the best behavior for the e.cars charging processes, etc. The same information, scaled to the whole regional area, is provided to the stakeholder, resulting to be a quantitative term of reference for the area energy planning and for the efficiency promotion policies.

3 Conclusions

The increase of pollution due to traditional energy resources is currently a central issue in the European Union agenda. Alternative solutions compared to the fossil fuels have to be considered. It is necessary to increase the RESs exploitation, optimize the energy consumption, reduce the system inefficiency and promote the auto-consumption and the local energy usage. In addition, the electric mobility has to be promoted by simplifying and optimizing the access to the recharge system. The **AlpStore** project tries to face the above mentioned challenges by proposing concrete innovative solutions with the aim to generate energy benefits, also on the environmental point of view. In fact, the TEAM pilot action tests an energy management system which coordinates RESs, storage systems and electric vehicles in order to cover the energy needs of an area and at the same time optimize the energy consumption and the reduction of the fossil fuels consumption. Probably, one of the main values of the project is the investigation of all the “chain”, starting from the “Theoretical Study” of the Region under analysis (to define the resources and the needs), moving to the design of a new energy model, to the discussion with the regional stakeholders and to the experimental demonstration of the approach proposed. Finally, all the results is reported on a public web area, shaped to be a live demo, i.e. the application of the model to “real data” collected in the Tecnocity area.

3.1 Regional potential of the tested local options

Concerning Storage solutions, in the short/medium horizon the only storage technology considered feasible for the Alto Milanese area is the electrochemical batteries; on the other hand for the long time scenario it is quite complex to identify the most promising technology. Considering EV applications (mobile batteries), the implementation model feasible in the Italian framework is based on a simple charging process in which the final users receive information about their energy behaviors and about the energy tariffs; collecting and evaluating all these information the users will use EV charging station without bounds. Actually, the users willingness to adopt an efficient behavior will results in the electro mobility impact on the electric grid. V2G (vehicle to grid) options are considered only for a long term scenario. In order to estimate the potential applications of electrochemical storage solutions the model adopted (technical requirements, energy functions, etc.) the following assumption has been adopted:

- Very short term scenario: each photovoltaic power plant is required to provide primary frequency regulation as a conventional power plant (i.e. it has to provide a regulation band equal to ± 1.5% on the nominal power) – the service is mandatory and not charged by an economic remuneration;
- Short term scenario: each photovoltaic power plant is required to provide primary frequency

regulation as a conventional power plant (i.e. it has to provide a regulation band equal to ± 1.5% on the nominal power), moreover an extra regulation band (up to 5% of the nominal power) is proposed under remuneration;

- Medium term scenario: each photovoltaic power plant could be coupled with a storage solution with the goal to modulate its production to meet a production plan or contribute to the energy balance of the grid (the service is supposed to be based on a market base, i.e. a special tariff will be introduced).

In Legnano area at the beginning of 2012 about 5.5 MW of photovoltaic power plants operate; the proposed planning procedure quantifies the optimal incremental photovoltaic power production for more than 10 MW (10 MW is here assumed as a reference, safe, value). Adopting the model proposed to the three references scenario results the storage potential market reported in Table 2[2]. Considering the three scenario proposed, experts in the field of energy and stakeholder involved in the project provide reliable estimations for storage deployment roadmap as depicted in table 3.

Table 2: Potential Storage market in Legnano area

	V. Short term Scenario	Short term Scenario	Medium term Scenario
Retrofit of the already in place PV gens	83 kW / 26 kWh	275 kW / 275 kWh	550 kW / >55 kWh
Integration with 10 MW new PV gens	150 kW / 38 kWh	500 kW / 500 kWh	1000 kW / >100 kWh

Table 3: Storage Roadmap estimation

	V. Short term Scenario	Short term Scenario	Medium term Scenario
Evaluation of the time horizon	Greater than 1 year	Greater than 2 year	Greater than 3/4 year
Retrofit of the already in place PV gens	unfeasible	Feasible if supported by an economic incentive scheme	Feasible if supported by an economic incentive scheme
Integration with 10 MW new PV gens	Feasible	Feasible	Feasible

3.2 Follow-up plans

With respect to the Alto Milanese framework, the administrative authorities and the energy operators cooperated in order to build up an effective new energy model. In particular, several actions have been activated in order to promote a proactive behavior for all the actors: the policies issued by the City of Legnano are in line with the implementation and application of the pilot action (and the STORM concept) developed within the **Alpstore** Project. Thanks to the TEAM Pilot action, several input about an "efficient" energy model for the area are now available. Actually, in the approach proposed Legnano city has been selected as a Big Demo application, in order to have an effective divulgation in all the municipalities of the Alto Milanese area. In particular, in the territory of Legnano the goal is to propose the new energy model to several industrial areas. Some of them are disused and need to be retrained, others are active industrial area that need an efficiency improvement or a carbon footprint reduction. The redevelopment of the industrial areas (disused and not), which imply also the redevelopment of the energy systems, is one of the most important political issue of the

[2] In order to correctly evaluate the figure it is necessary to point out that the area is fed by a single primary substation equipped with two HV/MV transformed sized at 25 MVA; the annual energy needs is about 110 000 000 kWh.

whole Alto Milanese area and, even more, of the Lombardy Region. Nevertheless, in order to ensure the establishment and the effective utilization of new approaches, technologies and infrastructure, it is important that the citizens are willing to accept these new technologies and infrastructure. The biggest advantage of Alto Milanese area is the great background in the Energy field from the industrial point of view, from the generation facilities and also from the Public companies/support offices who think and act independently (i.e. each one has a solid know how useful to directly apply trouble solving activities) and, in a second stage, a well-structured regional coordination and support program. Thanks to the web-demo based on the pilot action (http://62.149.217.122/AlpStore) and on the video and animation realized, the citizens are actively involved and encouraged to change their way of thinking and accept energy sustainable lifestyles, in order to accelerate efforts to effectively exploit the new technologies/resources.

3.3 Transferability to other Alpine regions

The TEAM pilot implementation represents a small-scale example of VPS which manages the energy resources available in the area to cover the energy demand and provide ancillary services for the main electrical system. The same model can be applied to other areas at transnational level which have RESs along their territory. Furthermore, the challenges related to the system stability and power quality of the electrical network are common all over the European interconnected electrical system. Therefore, the extension of the proposed methodology will be proposed at transnational level in order to solve a global problem.

Mantua, Italy
è rete luce
Case Study

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Case studies are contributing to AlpStore WP6
Work Package 6 Responsible: EUROIMPRESA LEGNANO s.c. a r.l.
Lead Partner: B.A.U.M. Consult, Ludwig Karg, Patrick Ansbacher, Anja Lehmann

1 Storage technologies for the region Mantua - general frame conditions and objectives

With a population of 418,000 inhabitants and 70 Municipalities widespread on a small area of 2,339 km2 with a density of 180/km2 the province of Mantova has always based its economic strength on agriculture: rural population was not affected by emigration. Economic problems of under development raised in the context of the general industrial development of Northern Italy.

Figure 1 - Map of the province of Mantua in Italy

Business structure

Trade and services 55%

Industry and manufacture 37%

Agriculture 8%

Status quo about sustainable mobility: few full electric vehicles (< 50 in the whole province), most of all owned by public or private enterprises (small cars/van for the delivery in the Mantua historical center owned by TEA public utility company for the waste collection, POSTE ITALIANE for mail delivery, etc.); many public or private hybrid vehicles (in particular for public transport: hybrid cars from the market, widely used as taxi, and hybrid gas turbine/electric bus owned and managed by APAM, public transport utility).

Figure 2 - The hybrid natural gas/electric public bus by APAM in Mantua town center

There are not EV public charging stations in the province. The Renault dealer offer the free charging service for their customers.

1.1 Actual and future regional energy system

The energy production is one of the main activity in the province of Mantova, that produces about 5 times its energy consumption, almost entirely by conventional power plants with fossil fuel, most of all natural gas.

The available data, drawn from the provincial energy plan and from TERNA statistics, show a critic situation in the province regarding energy situation, were the production of energy from polluting traditional sources is relevant, and the efforts towards the development of renewable energy sources is being developed, but is still in a start-up phase.

Mantua is the second province in Italy for installed power and energy production by thermoelectric plants. The first province is Brindisi, that is located on the sea, in an area subject of sea breeze and wind, where the dispersion of pollutants is easier than in the Po Valley, where the lack of wind facilitates their stagnation.

This big production is due to the presence of 4 main power plants. 3 of them were constructed during the last century and repowered after 2000 with the conversion to gas turbine groups. The Eni-power plant in Mantova it's a new plant realized between 2004 and 2006. Their total power is 3689 MW.

The energy production by conventional power plants is decreasing during the last years, for two main reasons:

- The economic crisis that reduced industrial production and final consumption and need since 2009;
- The increasing electric production by renewable energy sources that in Italy, by law, has priority input in the grid, and the energy saving solutions applied to buildings and industries, often supported and promoted by public actions.

The conventional plants investors are worried by the reduction of production and working hours of the plants, because their economic plans could be drastically modified.

During the last years, supported by national and local incentives and laws, new plants were realized, in particular, in the province of Mantova, photovoltaic and biogas plants. The Po Valley, has no wind and big waterfalls for efficient energy production.

Two new mini-hydro plants are under construction in Mantua and Goito. The total number of hydro plants is 6 with a total rated power of about 7 MW.

About photovoltaics systems, the total rated power in Mantova is about 150 MW for a total production of about 180.000 MWh. The total number is about 1650 with an average rated power 9 kW.

About biogas plants (with CHP), there are about 50 authorized plants in the province of Mantova (existing or in construction) for a total rated power of 60 MW and a total energy production of 440.000 MWh.

The grid in the province is completely developed, and all the villages are connected and supplied by the national grid.

The total consumption of electric energy in the province is about 3.700 GWh. Industry is the main consumer (2.400 GWh), than tertiary (600 GWh), household (510 GWh) and Agriculture (200 GWh).

The main energy storage in the province of Mantova is the tank farm for fossil fuels in the city of Mantova, on a side of the Mincio River. In these area there are 100 tanks owned by IES refinery with a total volume of 660.000 m^3 and a National store with 25 tanks and a total capacity of 23.000 m^3 .

The main renewable energy storages are represented by the gasometers realized in the biogas plants in the country of the province of Mantova: they are 50, scattered in the area, near small villages or in the middle of cultivated fields.

Considering a total power of 60 MW the total stored volume should be 60.000 ÷ 150.000 m3, 300 ÷ 750 MWh in terms of energy.

1.2 Regulatory framework

The objective of the “Lombardy Region Energy Plan” – the main document in the field of energy – is to ensure the regional energy demand, representing the 20% of the entire national demand, trying to maximize the utilization of the local renewable resources (biomass, waste, thermal solar, photovoltaic, hydroelectric) and to develop the utilization of clean fuel in transports and heating systems. A particular attention is dedicated at the renewable energies: development of plants and diffusion of information on energy saving. The aim is to double the contribution of the renewable sources at the energy supply system in Lombardy.

The Province of Mantova and AGIRE developed in 2008 and constantly update the provincial energy plan according to the guidelines defined by the Regional Energy plan, with the main aim of setting the conditions for the development of a sustainable and eco-compatible energy system in the area, the priorities of the provincial plan will be : renewable sources, energy saving, in order to attain a better environmental protection and an economic development that may be really sustainable.

The Municipality of Mantua and many others in the province are developing and implementing their SEAP, Sustainable Energy Action Plans, according with the Covenant of Mayors.

2 Pilot project Mantua: è rete luce

The sustainable mobility is moving from diesel/petrol engines to electric motors. This is actually the main road and trend. In the main cities, also in Italy, public charging stations for EV have been installed. In Mantua, before the **AlpStore** project, there were not public charging stations. The local public service company TEA is developing a plan to create many charging stations in Mantua, and in many other villages in the province, according to the requirements of the municipalities. This project is developed inside the larger plan of management of the public lighting of 30 municipalities of the province of Mantua. The requalified lighting grid will be used as a smart grid to manage new services as the EV charging stations network. Moreover, the new smart grid can involve renewable energy sources power plants in order to ensure green energy supply for the electric mobility.

The **AlpStore** pilot project is the first EV public charging station in the province and in the town of Mantua. It is an experimental model because it is equipped with a stationary electrochemical battery and its consumption is monitored together with the production of PV and biogas plants to try to define a suitable sizing for future applications, to measure the efficiency of the batter and to understand if the installation of the battery can really improve the system and be the right solution to connect renewable energy production and sustainable mobility, supporting the grid management.

2.1 Characteristics of the field test

The location is the center town of Mantua, in a restricted traffic zone that is accessible by free card for all the EV. The choice of the location considers many advantages:

- It ensures the visibility of the **AlpStore** pilot application.
- It is out of the traffic jam in a location that respect the traffic laws.
- It doesn't remove parking space for the other cars.
- It is close to many big residential and commercial buildings and to the Mantua historical center: it can be used in particular by the commuters from the rest of the province or by tourists during the day, and by the citizens during the night.
- It was easily served by the electric grid ensuring the needed power (50 kW).

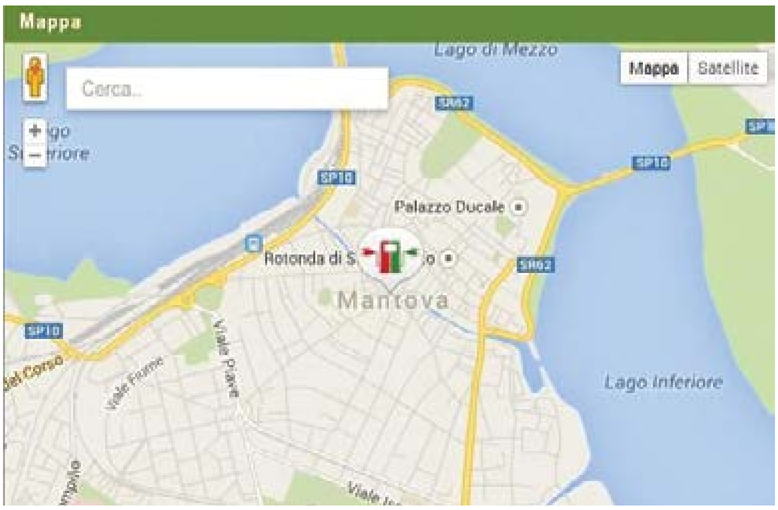

Figure 3 - Map of the AlpStore mantua pilot charging station

Figure 4 - AlpStore Mantua pilot webcam showing a private EV at the charging station

Figure 5 - The AlpStore Mantua Pilot: car, charging station and the technical cabinet with switchboard, plc, power meters, modem router, UPS and battery

The purpose of the pilot are:

- to measure the efficiency of the stationary battery, monitoring its energy consumption and the energy that the system delivers to the EVs;
- to check how many EVs are actually interested by the charging stations, how many vehicles will be registered to use it and how many of them will be use it, with which frequency, and how they will increase during the project;
- to size the elements of the VPS (renewable energy plants, battery, charging station and EVs users) to have a balanced system.

The pilot project was developed with the help of BMW Italia, that supplied for free loan a BMW I3 for 5 months, and its technical partner Gamma Energia that supplied the EV charging station for free. The charging station is connected to the grid and the power is supplied by the Mantua public services company TEA. The maximum power is 50 kW.

Figure 6 - The Schneider charging station applied in Mantua with the logos of AlpStore, Agire and local partners

Figure 7 - The tested car connected to the carghing station

The charging point has two Mennekes (type 2) sockets (22 + 22 kW). Charging is free till the end of the project pilot activity, and the connection is through a special card distributed by TEA registering the data of the user (vehicle and owner).

Figure 8 - Type 2 plug and socket

Figure 9 - Particular of the tested car during the charge with project logos

The Municipality of Mantua was involved and authorized the free occupation of public space for parking (two spots) and to install the equipments.

Agire bought the battery, installed by Gamma Energia, the webpage to manage the system (with personal page for each user and for the general management), monitoring all the data of accesses and consumptions. Agire also control the monitoring of the Virtual Power System, realized during the AlpEnergy project, consisting of 3 renewable energy power plants (2 PV, 28 kW and 1 biogas CHP, 80 kW).

The lead gel battery is a 8 kVA, 10 kWh. It's connected not continuously but only for test. The battery is constantly fed by the electric grid and maintained in charge, but the supply from the battery to the charging stations and the EV must be manually shifted from the grid supply. The size is not perfect but the aim of the project is to verify the efficiency and test the element to find the best sizing for future applications. Bigger size and different technologies were evaluated but they were too expensive for the local project partnership.

The local partnership includes Agire, official partner of the **AlpStore** project, the public service company TEA, the Municipality of Mantua, the car supplier BMW Italia and the technical supplier Gamma Energia.

Figure 10 - Installed Riello UPS

The charging station is also equipped with KNX communication protocol data logger and GPRS/UMTS modem router for a constant and continuous data transmission.

The data are collected and displayed by a new website: http://ereteluce.gammaenergia.it/ERete-Luce.

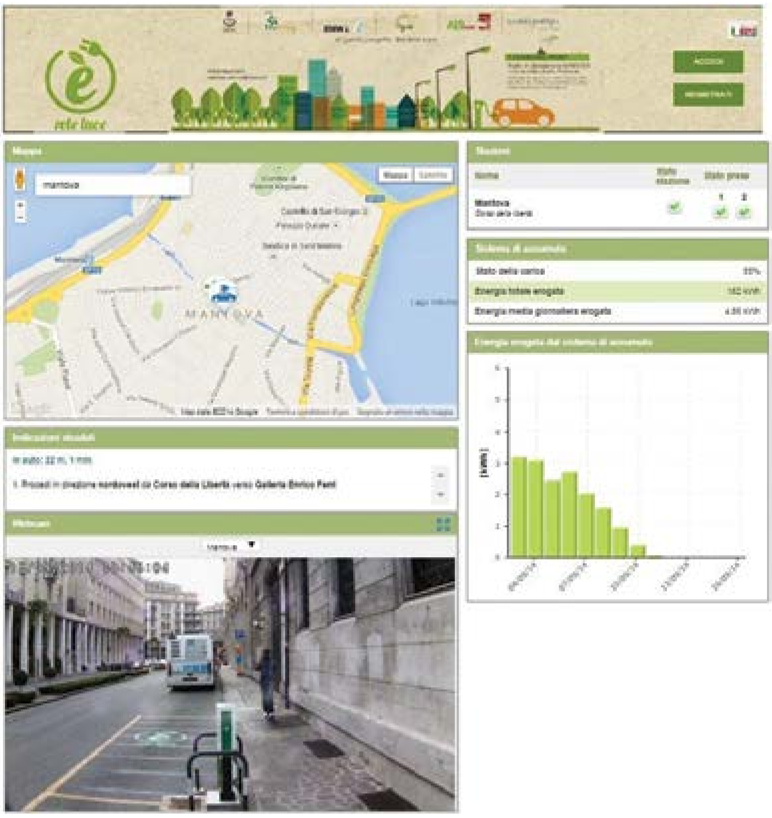

Figure 11 - è rete luce website with map, webcam, energy data and graphs

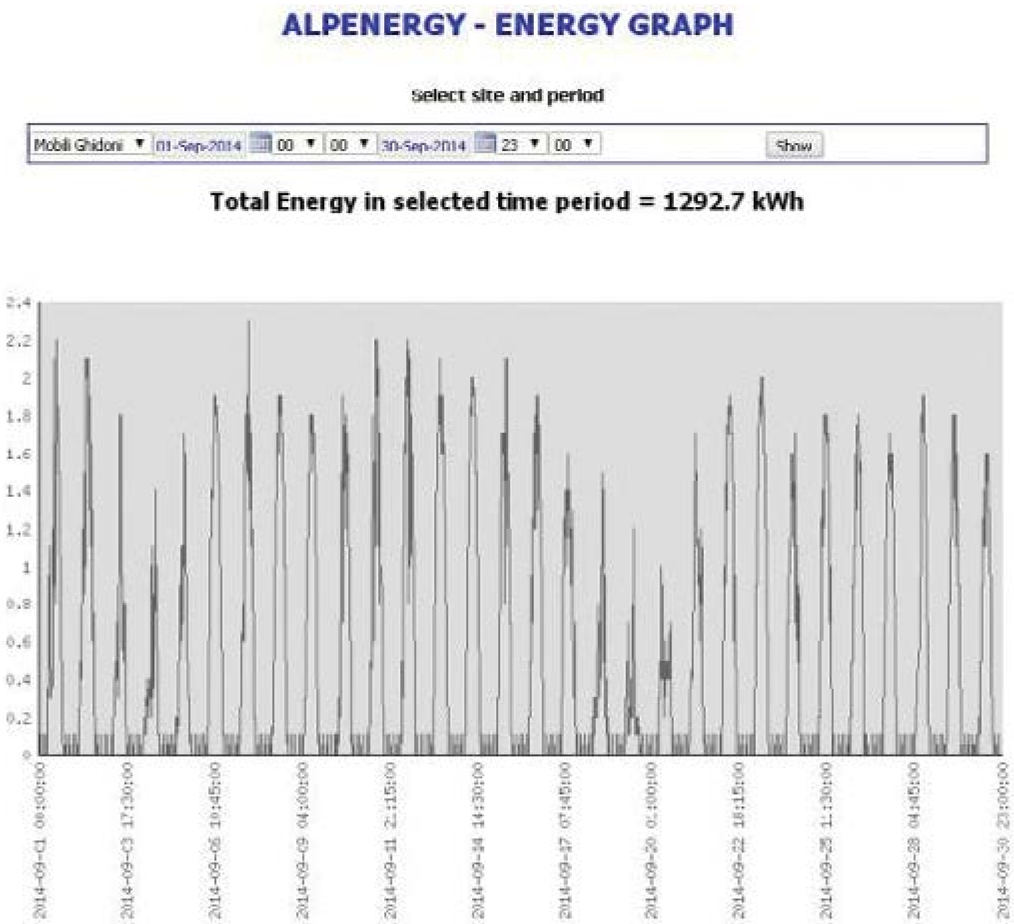

Figure 12 - AlpEnergy data and graph of a PV plant connected to the VPS in September 2014

2.2 Storage technologies and frame conditions

The choice of an electrochemical battery was adopted as it was the best solution for installation in a public area in the center town. The ventilated container will repair the lead-gel battery from too high/low temperature and tampering. The size and the type of the battery were selected to perform the test with an acceptable cost consistent with the budget. The cost of the battery was not included in the application form of the project and the partner support the investment with its own financial resources outside the project budget. Unfortunately, and partially expected, the results of the test show that the battery is exposed to a maximum operating temperature that exceeds the admitted range (0/+40°C). The higher temperature could easily compromise the expected life of the battery and its behavior. The battery could swell and crack and, in the worst case, some gel could come out. For this reason temperature is constantly monitored and, at the end of the **AlpStore** test, in May, the battery will be removed from the pilot charging station before summer.

The choice of the charging system and the kind of plug (type 2 – Mennekes) was according to the most common standards for the electric vehicles and for BMW that supply the car for the test. One car was supplied by BMW (free loan) and another car was rented by Tea with a 3 year contract. The charging station has been supplied by Gamma Energia for free as technical partner of BMW Italia.

2.3 Research design and schedule

The Mantua pilot has been planned from autumn 2013 till summer 2014. It includes both the technical design and the building of the local partnership. The starting point was an agreement with the multi service Company Tea to develop together the **AlpStore** Mantua Pilot and the public lighting management project of Tea. This project, regading also the implementation of many charging stations for electric vehicles in province of Mantua, connected with an ITC system by the lighting grid, was considered as an important action in the **AlpStore** Master Plan, while the Mantua pilot is also an important test for the next installations. During spring 2014 the choice of the location has been defined, involving also Enel Distribuzione, owner and manager of the medium voltage grid, and the traffic authority of Mantua. With the involvement of important technical partners, Gamma Energia and BMW Italia, and the administrative support of the Municipality of Mantua, the charging station with the battery was installed during June and July 2014 and it has been connected and officially opened in August 2014. Also the è rete luce website collecting and showing the data of the charging system is online and available from August 2014. The continuous monitoring is ongoing from August till the end of the project. Tests about the performance and efficiency of the battery are periodically performed.

Results of monitoring (from 8 August 2014 to 24 March 2015):

Total enabled users: 9

Total accesses (charging times): 174

Total energy consumption: 1.226 kWh

Energy supplied plug 1: 601 kWh

Energy supplied plug 2: 625 kWh

Average energy per charge: 7 kWh

Average time per charge: 70 minutes

Total renewable production: 8.000 KWh

Max battery system temperature: 50°C (August 2014)

Min battery system temperature: 10°C (January 2015)

Average efficiency of the battery: 65%.

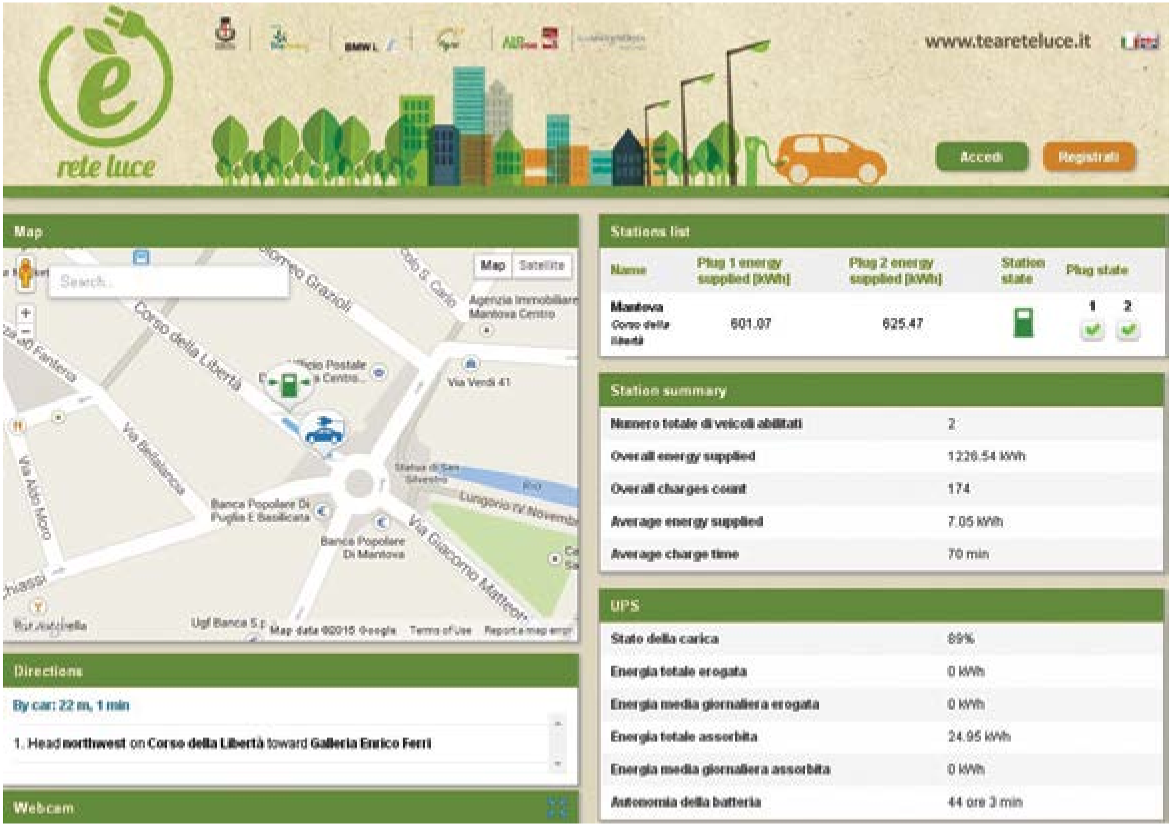

Figure 13 - è rete luce website with map, webcam, energy and UPS data

2.4 Implementation process

The project feasibility, design and implementation took more time than expected. The involvement of many local active partners, that helped to sustain the investments, required more meetings, compromises and a revision of some initial solutions. Other local technical partners were accurately investigated and evaluated. The initial location of the charging station has been changed considering the availability of the power and the need of the traffic authority. The final selected area has been prepared by the Municipality of Mantua, that needed to remove some barriers.

During the pilot actions some problems affected the test about the renewable energy production side: some plants connected with the VPS during the AlpEnergy project was broken and not able to work. In particular the biogas plant of 80 kW rated power in Suzzara, owned by a private farm, was constantly stopped by technical problems (feeding and engine).

The monitoring system has been based on two different websites: the old AlpEnergy data collector (managed by ICubo – University of Parma) and a new website for the charging station, created and managed by Gamma Energia following the requests and instruction of Agire and Tea. The final step will be the collection of all the AlpEnergy and **AlpStore** data in a single webpage on the new Agire website. The new website is still on development and is now still running offline.

Nein vehicles and users have been registered by Tea and are allowed to use the charging station. The list of the registerd car is available:

CARD NUMBER	MUNICIPALITY ADDRESS	KIND OF VEHICLE
1	SORGA'	RENAULT ZOE
2	MANTOVA	RENAULT TWIZY
3	SUZZARA	NWG ZERO TAZZARI
4	CURTATONE	ICARO GREENGO
5	ROVERBELLA	SMART ED
6	CASTELLUCCHIO	RENAULT FLUENCE
7	MANTOVA	RENAULT ZOE
8	NEGRAR	NISSAN LEAF
9	RODIGO	BMWI3

Main outcomes and benefits

2.5 Technical Findings

From the technical point of view the project has tested on field with a pilot application the feasibility of the outside installation of stationary battery in a public parking in center town. Registered temperatures of the system from august to January are included in the battery tolerance range.

The measured efficiency of the battery is quite similar to the expectation: 65%. It means that the renewable energy supply stored in a stationary battery is paid with a 35% of energy loss. It means that the energy charge could be affected by a several increase of costs due to the higher costs for production (longer payback time of renewable energy plants) and for storage (payback time of the battery and losses).

The original AlpEnergy VPS was connected to photovoltaics and biogas systems. Unfortunatly during the test period the biogas plant was constantly stopped because of a management problem of the farm owner of the plant. The monitoring was going on but no energy was produced and measured.

The measured energy production by photovoltaics was about 8.000 kWh with 15 kW rated power. With the current use of the charging station this production is more than six time the consumption. A 2,7 kW PV system could be enough to ensure the power supply to the charging station. Considering a constant use of the battery, the equivalent energy consumption in the same period should be 1900 kWh: in this case the PV plant produce four time the hypothetical consumption and the right size is 3,75 kW. Of course, the current use of the charging station is low: the total charging time is about 200 hours on a total available time of 10.700 hours (considering both plugs). It means that the electric consumptions of the charging station could be 50 times more than the measured optimizing its use with a widespread diffusion of electric vehicles. In this case the size of the pv plant should increase to 174 kW, considering the losses of a stationary battery of 60 kWh.

2.6 Economic effects

During the test the energy supplied by the charging station was free for the registered users and provided by Tea till the end of the LiCEA project. Generally the energy supply of a charging station costs more than the usual energy supply for a building or a company (a total tariff of 0,30/0,50 €/kWh instead of 0,15/0,25 €/kWh including taxes), due to the payback time of the investment. The total amount of supplied energy could have a value of about 600 Euro. Obviously the target is to ensure a similar tariff in the public charging station than at home (250 €). The supplied energy can ensure a total autonomy for about 7.300 km. Considering a gasoline car with a measured autonomy of 15 km/l the cost for the same autonomy (7.300 km) is 490 l that means 735 € in Italy, considering a cost for the fuel of 1,5 €/l. It means that during the **AlpStore** pilot application in Mantua EV users saved 600 Euro respect an EV charge in a public commercial charging station, 250 Euro respect an home charge, 735 Euro respect the fuel cost for a gasoline car (not considering the cost of investment for the different kind of car). The target in the future should be a cost of the energy supply in the public charging station that allows to halve the price respect a gasoline car.

2.7 Environmental impact

Considering an average emission value of 150 g/km of CO_2, 0,05 g/km of NOx, 0,005 g/km of particulate for a medium gasoline car, the total avoided emissions during the **AlpStore** pilot application in Mantua amount to 1,1 ton of CO_2, 0,365 kg of NOx and 0,0365 kg of particulate.

In the **AlpStore** master plan perspective for Mantua, considering 50 public charging station installed in the whole area of the province of Mantua and a use of each one for the 70% of the time, the avoided emissions per year could amount to 3850 tons of CO_2, 1280 kg if NOx and 128 kg of particulate.

2.8 Social benefits

Traffic is responsible of about 25% of emissions of NOx and particulate in the air. In the area of Mantua, as in the rest of the Po Valley, the level of the air pollution is particularly high, due to the traffic, domestic heating, power production, industry and agriculture processes. The situation is complicated by the persistent lack of wind. In this scenario it is qualitatively clear the benefit that a reduction of local emissions could bring, in terms of reduction of respiratory diseases, health care costs, etc. It is more difficult to quantitatively define these benefits.

The reduction of the CO_2 emissions in 2030 in the master plan perspective, considering a full realization in 2025, represent the 0,05% of the Italian target of reduction of CO_2 emissions in transport at national level for 2030 [1]. Extending this average results to all the Italian provinces, the approximate scale of contribution of the action at national level could arrive at 5% of the target.

The implementations of a new public charging station in a small towns as Mantua allows a more flexible and suitable use of the electric vehicle not only for small and medium distances but also for long distances. A good example was the transnational experience between the energy agencies Agire and EAR (Energy Agency of the Region) seated in Weidhofen an der Thaya (Austria) that had a meeting in Mantua on 15th and 16th December 2014 for the LiCEA project financed by the Central Europe Programme: the EAR staff decided to travel to Mantua experiencing EV on a long travel (730 km one way). They rented a Tesla car and travelled to Mantua with three stops of half an hour each in fast charging high power stations along the road (planned before the travel). They were able to charge the car in Mantua using the **AlpStore** pilot charging station. The EAR managers explained that the choice as not only an interesting test but also the most economic way to connect by car two small and distant towns of the Alpine area, far from the airports and the most important railway lines.

[1] Considering a total expected reduction in the transport sector of 37,3 Mt CO_2 within 2030 as reported in the study “Reduction of CO_2 emissions in the transport sector” by Sustainable Development Foundation (coordinator Raimondo Orsini).

Figure 14 - Transnational test of Tesla car charged at the Mantua pilot è rete luce with Agiere and EAR staff on 16 December 2014

3 Conclusions

3.1 Regional potential of the tested local options

The Mantua pilot application can easily be extended in the whole area of the province of Mantua (see 3.2 Follow-up plans), but also in Lombardy region. Lombardy Region is planning the installation of a widespread system of charging station and during the next months a regional public tender will be developed, published and managed. The request will be for charging stations open for any possible supplier, and probably without battery. The experience of Mantua pilot was disseminated to the regional authorities during two **AlpStore** seminars organized by Alot in Brescia and Milan and through a meeting in Milan between Agire and Lombardy Region.

3.2 Follow-up plans

The **AlpStore** Master Plan includes the project of Tea for the management of the public lighting in the municipalities of the province of Mantua. This project called Tea Rete Luce will provide also many new charging station in the town of Mantua and in the villages of the province. The plan is under development. The new station will be connected by a communication system based on the lighting grid: it will ensure the data communication between the stations and a central manager. This option is very important also for the connection of storage and renewable energy plants, also considering that Tea is owner and manager of many PV systems, micro hydro and biogas plants. In this sense the **AlpStore** model and the data resulting from the test will be important to evaluate opportunities and find solutions to the problems found out during the pilot test (for example the temperature of the battery).

3.3 Transferability to other Alpine regions

With appropriate adjustments, the Mantua pilot application results could be transfer to the whole Alpine Space region. About renewable energy, different kind of renewable sources could be consider as more available and less impact: mini and micro hydro and wind plant together with PV plant could substitute biogas plants in many Alpine regions. Considerations about the storage size and the kind of battery and its location have to be done, taking in account the climatic peculiarity of the area and the selected mix of renewable energy sources. Strategic considerations about the opportunity of development of the electric mobility in mountain areas with high gradients of height have to be analyzed. Please refer to other **AlpStore** case studies for more information about this topic.

Burgenland, Austria
ÖkoEnergieland
Case Study

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Case studies are contributing to AlpStore WP6
Work Package 6 Responsible: EUROIMPRESA LEGNANO s.c. a r.l.
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1 Storage technologies for the region ökoEnergieland - general frame conditions and objectives

The region of ökoEnergieland has made a fundamentally decision for its future – to take the energy supply stepwise into one's own hands in order to use the own regional resources. This includes the creation of added value, jobs and more independence from energy imports.

1.1 Actual and future regional energy system

For the project **AlpStore** the pilot region called ökoEnergieland was chosen based on the already existing activities in the field of bioenergy. Following an overview of the regional production and consumption is given.

Heat demand	214.373	MWh
Heat production	172.034	MWh
Covering ratio	80%	

Electricity demand	101.699	MWh
Electricity production	37.500	MWh
Covering ratio	37%	

Fuel demand	134.633	MWh
Fuel production	0	MWh
Covering ratio		

Total demand	450.705	MWh
Total covering ration	46%	MWh

Heat and electricity demand	316.072	MWh
Covering ratio of heat and electricity demand	66%	MWh

Electricity

The production of electricity within the ökoEnergieland is mainly done by the Biomass CHP plant, Biostrom power plant and the Biogas plants. The produced electricity is fed into the public grid. The public grid is operated by the company Netz Burgenland Ltd., except the local grid in Güssing, which is operated by the local network operator.

District heating

Based on the richness of biomass in the region, the input material used for the district heating supply is biomass of forestry and agricultural field. Therefore the thermal heat produced out of the district heating plants as well as the waste thermal energy of the biogas and biomass power plants are fed into the regional grid.

Future regional energy system

- Biogas for heating purposes

The region of ökoEnergieland is characterized by scattered settlements and that's the reason for the circumstance that only houses in communities town centres were able to be connected to the biomass district heating grids. Now the plan is to construct an area wide biogas grid in order to supply all those settlements too. The houses are then going to be heated by gas central heating with the help of special biogas heaters. The regional biogas plants (anaerobic digestion plants) will be connected by main pipelines and in the communities itself local networks will be constructed. Decentralized biogas storage units will provide uninterrupted service.

- Biogas for refueling purposes

Bio-methane will be produced by decentralized upgrading plants located at some communities in ökoEnergieland. These upgrading plants should be coupled with the biogas grid and the gas filling stations should be providing bio-methane for citizens, enterprises and regional public transport.

- Regional supply feedstock

To guarantee a sustainable supply of feedstock in an available diversity a communal feedstock association is required. On the basis of the already existing communal drinking water association or association for sewage treatment, which are operated very efficient and successful for years, the unused potential of forestal, agricultural, private, communal and industrial residues should be collected and utilized. The association's staff members are in charge for management, temporary storage and supply of energy plants. The financing of the association is covered by the sale of feedstock.

1.2 Regulatory framework

Because of the special economical, structural, technical and physical properties of the energy economy, the electricity and gas laws play an important role by handling different topics. These laws are linked to the production, transmission, distribution, sale and trading of electrical energy and gas. In Austria there is no law, which handles with the topic of energy storage in particular. All the mentioned topics are written down in laws, which have a strong link to other areas.

National Legislation

The E-Control, which is responsible for the regulation of the electricity and the gas industry market, has undertaken to provide translations of a number of major Austrian energy acts into English to inform interested readers about the national legislative situation. Most important are three laws, which describe the situation about legislation in the sectors electricity, green electricity and gas.

"Gaswirtschaftsgesetz"

This federal law provides rules for the organization of the natural gas sector in Austria. The purpose of this Federal Act is to enact provisions on the transmission, distribution, purchase and supply of natural gas, including network access and access to storage. The further purpose of the federal act is to regulate the system charges and provide rules on billing, internal organization, unbundling and transparency of the accounts of natural gas undertakings and to provide for other rights and obligations of natural gas undertakings; as well as to regulate the construction, extension, alteration and operation of natural gas pipeline systems.

Legislation for mobile Storage systems

At the moment there is no legislation for mobile storage systems (EVs and PHEVs) which attends to manage these kinds of storage systems. A standard norm (ISO 15118 – Road vehicles – Vehicle to grid communication interface), which take care of a standardization between the electric cars and the charging infrastructure, has been developed to handle with this special topic. At the moment the norm is under review. It shall adjust to the communication between the electric cars and the charging infrastructure and shall define a common standard or a standardized protocol. With this ISO 15118 it should be possible to get a hand on managing mobile storages in the future. A standardization of the total electro mobility market is at the moment a wishful thinking, because problems like standardized plugs, infrastructure, roaming, etc. are problems which are not so easy to be solved in the near future.

2 Pilot project ökoEnergieland

2.1 Characteristics of the field test

Location

The ökoEnergieland is an association of 18 communities in the south part of land of Burgenland. ökoEnergieland consists of communities of the districts called Güssing and Oberwart. This region is known as a region with low economy and low developed infrastructure. This was the reason why the region was chosen, to increase the added value of the region and to find new opportunities and chances for energy supply. The implementation activities are going to be realized mainly in the small village, called Strem. This municipality consists of 4 urban districts which are Deutsch Ehrensdorf, Steinfurt, Strem and Summetendorf.

The region is covered with up to 50% of forest, followed by agricultural fields, which have important resources for energy production like corn, cereals, rape and sunflowers.

Purpose of the pilot

The aim of ökoEnergieland is to substitute heating oil with biomass and to increase renewables as much as possible. Several communities in the ökoEnergieland region are already supplied with heat by biomass district heating grid. Major parts of the region are characterized by scattered settlements and this was the reason why only compact settlement and houses in community's town centers has been able to be connected to the biomass heating grids in the past. In order to tackle this problem and to provide a low priced convenient and environmental-friendly heat supply also for those settlements an area –wide biogas grid with a total length of more than 300km should be constructed gradually in the next years.

Due to these facts and the existing research biogas plant in the small village Strem, the place has been chosen for the start of building a new successful model of energy self-sufficiency supported by activities out of **AlpStore**. The main idea is to supply with the biogas grid the urban districts in the region that are too decentralized to be connected to the still existing local heating system.

The biogas is generated out of renewable resources of the region in biogas plants and can be used to supply end users for heat production. Apart from agricultural products as maize silage and grass also green waste of public and private land, agricultural intermediate crop, maize straw, etc. are sources to produce biogas for biogas grid to supply the scattered households.

Selection process

Different studies were made to analyse the rural region of ökoEnergieland during the last years. Based on already realized technologies in Strem (biogas plant, district heating system, PV plants), which will give best conditions for future projects, it has been decided for the overall region that also the planned biogas grid and all implementations should be spread out from Strem to other villages.

In the course of the **AlpStore** project therefore the first negotiations with the supplier of the technologies for biogas heaters, biogas storages and biogas grid were held.

Important also has been to conduct an evaluation of the private houses, to get to know if there is a general interest to connect to a biogas grid, mainly in the scattered parts of the region.

Involvement of the Stakeholders

The main group of the partnership has been the core board of EEE which is responsible for the identification of barriers to market expansion of renewables. In the project region the members of the core group are quite different and include not only members of the provincial government but also suppliers, agricultural experts as well as financial managers.

Based on the cooperation of the EEE and the involved communities in the ökoEnergieland a working group was established. The working group is build up from the mayors or chairman of the leader of the working group. The CEO of EEE, Mr. Reinhard Koch, together with Sebastian Koch, the manager of the model region, are like a pool between the communities in the ökoEnergieland and the company EEE. Based on his employment in EEE and the activities with the communities they became to the model region mangers, who are permanently involved in the project management, and therefore have the know-how of the latest technologies, policies or implementation possibilities of renewable energy. Furthermore, that network caused in beneficial position not only for the communities, but also for citizens to be like a contact and helpdesk point.

Relevance for the future

The implementation of the biogas grid should be optimized in the first step for the trial grid and then stepwise for the whole region of ökoEnergieland. For the future it should act as a best practice for the southern part of the Burgenland province as well as for the whole land of Burgenland.

The main focus in ökoEnergieland is on regional energy sources like forest and biomass from the agricultural fields, but there are new activities in the region which coming up thanks to the **AlpStore** Projekt. Based on different analyses of the input materials also utilization possibilities were advertised for the output material of a sewage treatment plant. As it will not be allowed in the future to use the output material as manure for the agriculture fields, it is planned to put it in thermal gasification process to produce biogas. The idea behind is to connect all energy plants, which are producing biogas and put it to the biogas grid for supply chances.

2.2 Storage technologies and frame conditions

The 2010 National Renewable Energy Action Plan for Austria presents measures to achieve an increase to 34 % by 2020, of renewables as a share of gross energy consumption (in line with EU Directive 2009/28/EC). Compared to a reference scenario based on the data on energy consumption available up to 2009, final energy consumption is to be cut by 13% by 2020 in order to achieve the target.

- **Hydropower and biomass:** Austria was one among four EU countries with the highest share of energy out of renewable sources in gross final energy consumption in 2005. Since 2005 the share of renewable energy in Austria had grown continuously, reaching nearly 29% in 2008. The main driver for the growing contribution of renewable energy is the enhanced use of biomass due to strong incentives such as targets set by regulations a long-term focus on research and development policies as well as subsidies.
- **Wood biomass for heating purposes:** Wood biomass for heating purposes has always played an important role in the Austrian energy supply. In 2009, more than 70.000 pellet boilers were installed with a power capacity of 1,356 MW. Over 1,000 biomass district heating stations have been constructed in rural areas since the 1980s, often with subsidies providing the decisive incentive. Hence, biomass boilers made in Austria nowadays represent one of the best available biomass combustion technologies worldwide.
- **Green electricity legislation:** Green electricity legislation was introduced in 2002. In 2009, electricity produced from biomass under the green electricity scheme accounted to more than 2,500 GWh corresponding of around 5% of total electricity production. In 2004, Austria's government adopted an ordinance on biofuels exceeding the targets of EU Directive 2003/30/EC (2% share in 2005, 5,75% in 2010) resulting in a 7% share of biofuels in 2009.
- **The objective:** The objective of the recently elaborated energy strategy is the development of an energy system providing energy services to private consumers and businesses in the future while complying with EU climate and energy requirements.
- **Data for 2010:** The Austrian gross national consumption of energy for the year 2010 was 404.906 GWh (increase of 6,7% compared to 2009). The share of renewable energy has been 30,8%. The biggest share of renewables has energy out of hydropower with 39,5, followed by solid biomass with 32,4% and renewable energy in the district heating sector with 8,5% and biofuels with 6,1%. The rest of 100% is produced by other renewable energy sources like wind power, photovoltaic, solar thermal, biogas, etc. By using renewable energy it was possible to avoid greenhouse gases of 15,989 Mio. tons (CO_2 equivalent) in Austria in year 2010. The total sales volume of all investments related with the operation of renewable energy was 5.229 bn € in the year 2010 (increase of 5,1% compared to 2009). 37.649 employees worked in the relevant sectors of production and service (increase of 1,9% compared to 2009).

A compressed overview for the relevant institutional and legal framework provides the following figure.

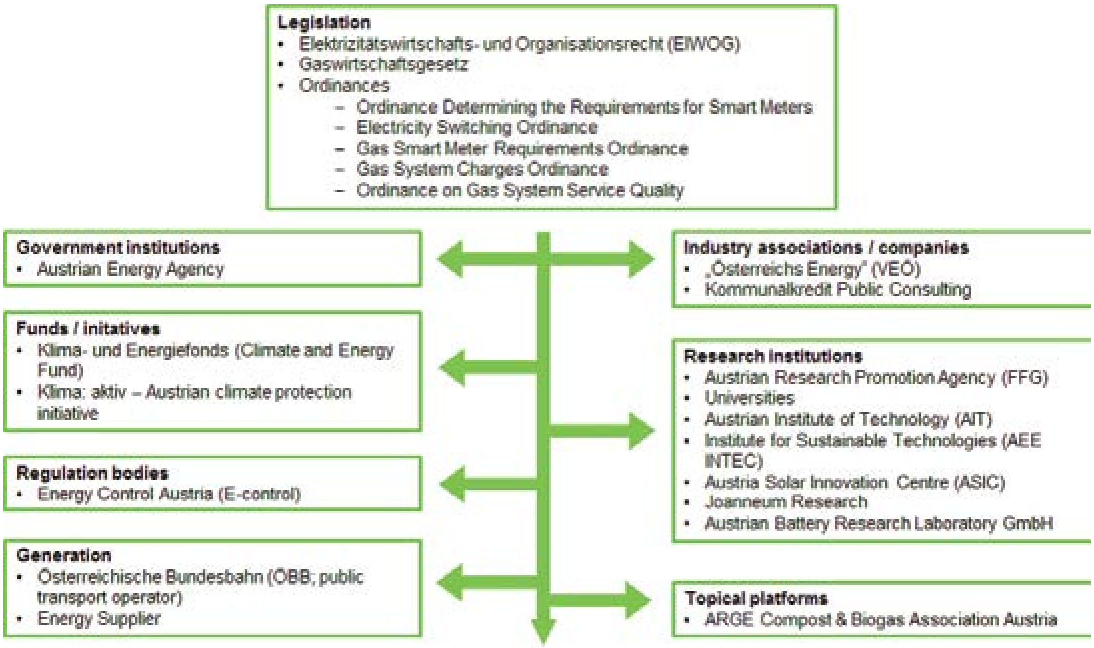


Figure 1: Institutional / legal framework Austria (Source: Keglovits & Hartmann, 2013)

In January 2008, the European Commission presented a legal package on climate protection which is often referred as to the 20-20-20 targets. The proposals focus on a restrictive climate and energy policy and set new goals. By 2020, Europe shall therefore:

- cut greenhouse gas emissions by 20 %,
- increase the share of energy from renewable sources by 20 %,
- increase energy efficiency by 20 %.

The burden of reducing greenhouse gas emissions will be shared by the Member States on the basis of their wealth. Austria is committed to reducing emissions by 16 % by 2020 as compared to 2005. This target applies to all emitters not subject to the emissions trading scheme set out in the European directive 2003/87/EC. However, this emissions trading scheme should also be further developed and more restrictively applied. Apart from the fact that, from 2010, certificates will no longer be distributed free of charge, the sectors subject to the emissions trading scheme will be assigned a reduction target of 21 %. The new directive on carbon capture and storage is another important component of the efforts in climate protection. This directive promotes relevant technologies and the practice of geological storage of CO_2 emissions. Finally, the third pillar of the 20-20-20 targets is raising the share of energy from renewable sources. By 2020, the share of energy from renewable sources shall be increased to 20 % of total energy consumption, i.e. not only regarding electricity, but also heating, transport, etc. The contribution for Austria is an increase in this share from 23.3 % in 2005 to 34 % in 2020.

The Kyoto Protocol

At a supranational level the Kyoto Protocol has been the central instrument of climate policy. All EU member states have agreed to share the climate burden and have committed to individual climate protection targets.

The Austrian target is a reduction of greenhouse gas emissions by 13 % as compared to the base year 1990 by the end of the so-called Kyoto period. An Austrian climate strategy for target attainment defined a series of instruments and measures, which cover all important areas, from the renovation of residential buildings, traffic regulations, the optimization of processes for the generation of electricity and heat to the promotion of renewable energy technologies. So far, these efforts have not produced the expected results. Current values of greenhouse gas emissions in Austria significantly exceed the original Kyoto targets - i.e. 15 % above the base value of 1990.

- *The energy end-use directive*

Another central point of European energy policy is the energy end-use directive. It stipulates an increase in energy end-use efficiency by 9 % by 2016 compared to 2006. This target does not require a "real" reduction in energy consumption in absolute numbers but a more efficient use of energy, i.e. driving more kilometers with the same amount of gasoline. Last but not least the common energy policy strives for a significant increase of the share of energy generated from renewable energy sources in Europe. This applies to both the energy end-use (i.e. heating, bio-fuels for vehicles) and transformation processes in the generation of electricity and heat.

- *Energy Strategy Austria*

The aim of the "Energy Strategy Austria" is the development of a sustainable energy system, energy services for private consumption as well as for companies. The defined goals should provide the EU targets on climate and energy (20-20-20, Kyoto Protocol). Security of supply, environmental impact, cost, energy efficiency, social equity and competitiveness were fixed as frameworks in the Austrian energy strategy. In working groups concrete measures should be defined. Concerning storages and e-mobility two working groups; "storage and grid" and "mobility"; have been implemented.

Storages

Concerning storages further studies shall be conducted. Important topics in this case are CCS, gas storages and "environmental friendly storages". Different market players (e.g. energy suppliers) will get an order to create helpful studies.

EVs and PHEVs

In 2020, in total 250,000 electric vehicles (proposed all-electric vehicles and plugin hybrid vehicles) should be on the road in Austria. This represents a ratio of not almost 5 percent of the forecast of the total number of passenger cars in 2020.

Klima- und Energiefonds (Climate and Energy Fund)

The climate and energy fund is an institution of the Austrian government. It was founded in 2007 and has the goal to reduce greenhouse gas emissions in Austria by setting targeted pulses and initiating funding for projects. The Climate and Energy Fund is therefore a key instrument of the Austrian government for the achievement of climate protection (20-20-20 targets, Kyoto Protocol), higher energy efficiency (the energy end-use directive) and the development of innovative renewable energies. Since 2007 in total 35,000 energy and climate projects have been implemented with a total budget of € 600 Mio by the Climate and Energy Fund. The Climate and Energy Fund is responsible to keep the European targets (20-20-20) in mind and promote a "zero emission Austria".

For the efficient operational implementation of the funding allocation the Climate and Energy Fund is supported by management agencies. These are currently the "Österreichischen Forschungsförderungsgesellschaft mbh" (FFG), „Kommunalkredit Public Consulting GmbH" (KPC) and the „Schieneninfrastruktur-Dienstleistungsgesellschaft mbH" (SCHIG mbH).

Projects concerning energy storages and also smart grids, which also include the topic of storage, are big issues in the different programs. The following programs of the Climate and Energy Fund, which have a close link to energy storages, are registered in the following list.

- *Smart Cities – FIT for SET*

This program attends to the topics renewable energies, energy efficiency, mobility, e-mobility and model regions. The vision of the Climate and Energy Fund for the program "Smart Cities - FIT for SET" is the first implementation of a "smart city" or a "smart urban region" and also includes neighborhoods, communities or other urban regions in Austria. The main task lies on the implementation of intelligent green technologies to build up a "zero emission city" or "zero emission urban regions" with a high quality of life. The program focuses on the areas of buildings, energy networks, supply and waste management, mobility, communication and information. The storage of energy is therefore an essential way to achieve the objectives, which are defined in the "Smart Cities – FIT for SET" program.

- *Smart Energy Demo – FIT for SET*

The central objective is the implementation of the visible "Smart City" pilot and demonstration projects in which existing and already largely mature technologies, systems and processes are integrated to interacting global systems. The key strategic objectives of the program are aimed at improving energy efficiency, increasing the share of renewable energy sources and the reduction of greenhouse gas emissions.

- *Neue Energien 2020*

This program attends to the topics renewable energies, energy efficiency, smart energy and awareness. In the program, ideas and concepts with long-term prospects have been realized by basic research and technological research and development work and implemented through pilot and demonstration plants. In addition to these primarily technology-related issues, the program has to work out the task to address social issues and knowledge for long-term planning processes. The program closed in 2011. The objectives of the program will be continued in the new program "e!Missi0n+.at – Energy Mission Austria", which started in 2012.

- *e!Missi0n+.at – Energy Mission Austria*

This program attends to the topics renewable energies, energy efficiency and R&D. This program pursues the Climate and Energy Fund, aims to reduce the cost of high-efficiency and low emission energy technologies and helps to ensure that Austrian companies play in this rapidly growing sector a leading role. The focus lies on collaborative projects between industry and science. The program is designed to convert scientific breakthroughs into innovative and sustainable products and services that provide business opportunities and make a contribution to reduce greenhouse gas emissions significantly.

Local storage of biogas

Biogas is essentially a mixture of CH4 (methane) and CO_2 (carbon di¬oxide) and presents a form of chemically bound energy. It might be stored at atmospheric or higher pressure in suitable recipients before further conversion into other forms of energy. This might be tanks, which are installed close to the digester and close to the facilities, which make use of the biogas for electricity and/ or heat generation, e.g. a combined heat and power plant (CHP), a motor-generator without heat use, a biogas burner for cooking, a hot water boiler or a room heating device.

The construction of a larger local biogas store is a suitable option if the local consumption of biogas is widely not in pattern with the production. In addition, it is a suitable option if the alternative of up grading the biogas is not suitable because the biogas is not situated in the vicinity of the existing natural gas grid or is not big enough to allow for economically viable upgrading of biogas to biomethane (almost pure CH4). Larger biogas buffer stores permit for instance to operate a CHP. Larger biogas buffer stores permit for instance to operate a CHP more flexibly with stronger electricity and / or heat output variations. A higher CHP nominal power can be chosen in connection with a larger biogas store because the store allows supplying the CHP temporarily with a biogas input rate above the digester's bio-gas output rate.

- *Local storage if heat produced by a biogas-fed CHP:*

If the biogas is used for fuelling a CHP, a heat store is usually installed for buffering differences between the heat generation and demand. If the CHP is now run in the electricityled mode and the electricity production is strongly fluctuating, e.g. because the CHP produces balancing energy to stabilize the grid, not only a larger biogas buffer store, but perhaps also a larger heat buffer store is required. In order to ensure that, sufficient heat is supplied even if the CHP output is low because of lacking electricity demand.

The heat buffer store does not necessarily need to be larger when the CHP operation is electricityled compared to the usual operation at more or less constant power (i.e. in the base load mode). In the latter case, a sufficiently large heat buffer store is needed anyway because heat is produced often at times when there is no need for it.

An alternative to enlarging the heat buffer store is decoupling and varying the ration of electricity and heat production. This leads however to a lower overall CO_2 reduction because the electricity production per unit of biogas in no longer maximized and renewable heat avoids less CO_2 than renewable electricity as along as the power plant mix is still dominated by fossil power plants.

- *Local storage of up-graded biogas (biomethane):*

Biogas can be up-graded to bio-methane through almost complete removal of all other gases than CH4, notably removal of CO_2. Biomethan can then be stored in suitable recipients at atmospheric or higher pressure close to the digester and close to the facilities which make use of the biomehtane.

This option is only of interest if the use case requires the almost complete removal of all other gases than CH4. This is necessary for use as transport fuel in vehicles with a suitably adapted gasoline engine or if consumer devices are used which are not adapted to biogas. While the latter is rather the exemption, the former is one of the most important forthcoming applications for biogas. In both cases no connection to the electricity grid exits and the storage has no role in the electricity grid.

- *Storage of up-graded biogas (bio-methane from biogas) in the natural gas infrastructure:*

Storage of bio-methane in the existing natural gas grid and gas stores is possible after pressurizing and injection into the grid. This option is the most suitable one if the local production of biogas is much higher than the amount of biogas that can be used locally for electricity and / or heat production. In such case of a rather large biogas plant, it is often also possible and economically viable to install a new biogas pipe to the existing natural gas grid even if the latter is at some distance away.

Barriers and challenges

A phasing out of fossil energy was the main target of the pilot region, years ago. The idea was to get independent in the field of thermal and electric energy regarding to the private houses and public buildings in the first step. The following step should be consequently covering the energy demand of all sectors also industry and transport with renewables in all energy forms as heat, electricity and fuels.

Different measures mainly in the private and public sector were settled down to reach the energy self-sufficiency in the field of thermal energy. However, the baseline for such activities is the establishment of the regional feedstock association, as well as a foundation of subsidiary manufacturing company, which should take over diverse energy-related activities as implementation of projects.

As the next step, the electricity self-sufficiency has been planned for the pilot region. Also for this stage different measures are necessary to reach the goal. Fundamental corner support is the implementation of photovoltaic stations in the communities of ökoEnergieland based on public participation financing model, as well as on the restructuring of the street lighting to LED system.

The field of e-mobility should be as the last stage to reach the energy independency of the fossil energy. With an installation of biomethane filling station and various e-mobility programs, it should be possible to build up a network for the transfer in this pilot region.

The comprehensive intention, to have a complete supply chains and to assure this energy self-sufficiency should be relief on a biogas grid. A grid with a length of up to 300 km should connect all communities in the region, and what's more, it should be like a backup system for the peak power, if there any of the energy form is going to be needed. The baseline for all these energy activities is the extensive activity of awareness rising by the citizens.

2.3 Research design and schedule

Initial situation

Several communities in the ökoEnergieland region are already supplied with heat by biomass district heating grids. Major parts of the region are characterized by scattered settlements and that's the reason for the circumstance that only compact settlements and houses in community's town centres were able to be connected to the biomass district heating grids. In order to tackle this problem and to provide a low priced, convenient an environmental-friendly heat supply also for those settlements, an area-wide biogas grid should be constructed gradually in the next years.

Objectives

The first step for the overall implementation is to build up a trial gas grid of about 2,5 km length from the biogas station to the scattered settlement of Stremer Bergen. The following step will be the connection of 7 municipalities of the south of ökoEnergieland (Strem, Heiligenbrunn, Großmürbisch, Kleinmürbisch, Inzenhof, Neustift and Heiligenkreuz). In most of the 7 municipalities district heating exists. Therefore biogas grid should not only connect the municipalities, but also the peripheral situated household, where supply of district heating system isn't possible.

To get an overview of the interest of the private, different presentations of the activities of the concept region as well as negotiations have been made till now.

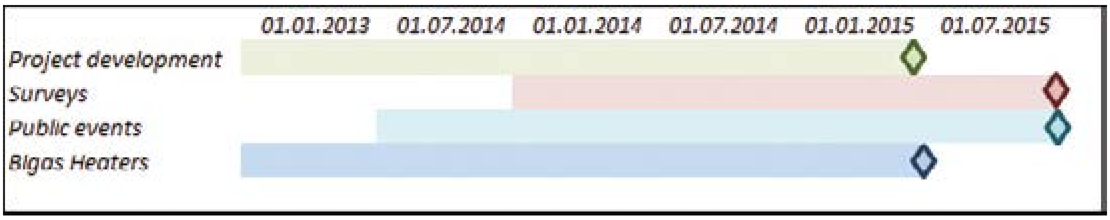
Based on the surveyed data, calculations for 3 variants have been made so far, one scenario has been selected out and should be brought to implementation. The expected results are up to 26 km of the main lines with up to 387 connections to private households as well as up to 9 km bypass lines with 171 connections.

Expected calculated gas demand in the region:

Municipality	Gas demand MWh
Strem	1,290
Heiligenbrunn	2,370
Großmürbisch	1,760
Kleinmürbisch	1,040
Inzenhof	1,685
Neustift	2,045
Heiligenkreuz	380
Total	**10,570**

An essential element of a biogas grid is the included biogas storage to support an interferences free service and to encourage the workflow of the biogas heaters for the households. Therefore, important meeting have been taken to calculate the dimensions of this grid.

Relevant for the project **AlpStore** is the following timetable. In July 2014, important workshops and meeting were held with the project partner Viessmann. The results and estimations of the testing of biogas heaters were discussed and terms for the following cooperation were settled down. The important result is that the biogas heaters are suitable for such biogas compound and it can be started with the implementation. However, necessary for the implementation was to find an investor for this intention. Fortunately, the last negotiations with investors were very successful, so the implementation should start as soon as possible.



2.4 Implementation process

The already existing biogas stations accomplish a good baseline for implementation of the biogas grid project. Regional resources are used as a feedstock for electricity and thermal energy production, which also tracing the goal of independency. The surplus of the thermal energy produced out of bio-gas is put into the existing district heating system, which is characterized by a high waste power. Precisely because of that losses problem, the biogas grid should be developed in ökoEnergieland.

The implementation of the biogas grid in Strem as well as in the overall region is of course the main goal for the next years. Within the course of the project **AlpStore**, different analyses for the implementation of this project were developed in cooperation with important partners, like Viessmann.

At the beginning of the planning and implementation stages, the project faced some policy frameworks and financing problems. Nevertheless, to ensure even the economic feasibility the process of pre-contracting with the private sector has been started. This activity should give an overview of the interest as well as acceptation of a biogas grid in the region. To provide the security of the energy supply in the region, it is also planned to build up three additional biogas plants, which also require a save feed-stock management. Therefore, the concept of this feedstock management was the baseline to establish a feedstock association in the region, to use and gather the unused resources like green waste from the private or public areas, the waste grass of water's edge or others. These and other forms of resources are a form of waste for the municipalities, for which huge costs incurred for the transportation. Though, based on the analyses from the Technical University Vienna, all these resources are ideal input material as for the biogas plant as for the district heating systems.

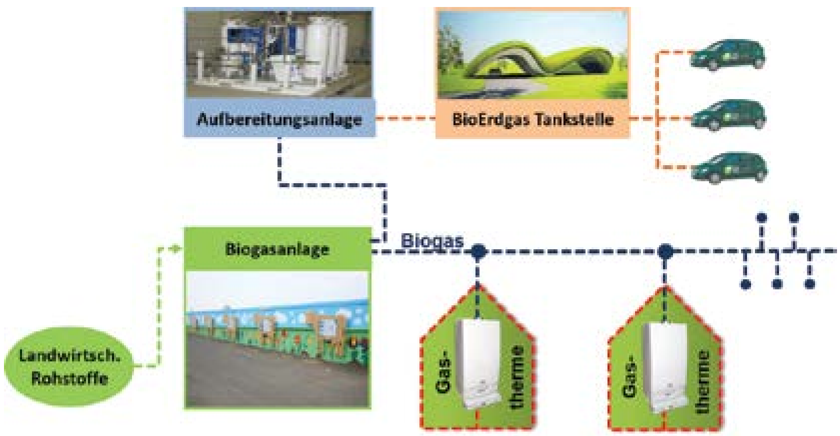
3 Main outcomes and benefits

3.1 Technical Findings

Biogas grid

To guarantee a safety supply of the private households in ökoEnergieland as well as the biogas for the planned gas filling station and biogas store, a perfect planning process should be developed before-hand.

The biogas grid will be implemented in each community of ökoEnergieland and will supply all private household of scattered settlements. Meanwhile, there are about 6.000 private houses, which are located at the biogas grid, less the private houses, which are currently supplied with district heating system, geothermal energy or heat pump. There is a forecast of up to 3.000 private houses, which could connect to the biogas grid in the next years. Additionally, there should be a connection of the industry and trade companies.



Graphic 1: Key visual of the case study biogas grid in ökoEnergieland

Biogas heaters

In cooperation with our partner Viessmann, biogas heaters have been developed, which exactly match the requirements of the planned biogas grid. The pilot heaters were analyzed and tested directly at the biogas facility over 2 years.

These biogas heaters will have to have a function like a transmission station by the district heating system and will be installed directly at the private houses with a connection to the biogas grid. With these biogas heaters it will be possible to produce thermal energy for heating and warm water purpose, but it will stay in the operators' own, who will be liable for all service, repair and emergency cases.

That's model of the company Viessmann can be easily retired in a niche of bathroom or in a cellar on the wall. It is furnish with an Inox-Radial-Transmission station from high quality steel, which offers the required reliability and guarantees a long-lasting utilisation of caloric value. Thanks to this, less energy will be used which also occurs lower heat costs for the enduser and an effectiveness by 98%.

Graphic 2: Illustration of the biogas heaters of company Viessmann

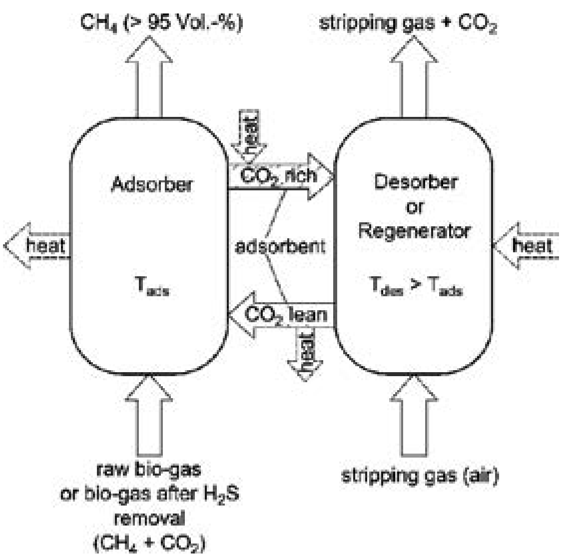
Biogas treatment for refueling

Temperature Swing Adsorption (TSA) is very often used for treatment of biogas for filling purpose. By a TSA – process a solid adsorbent is in position of absorbing selective one or more gas components coming from gas stream. The amount of the adsorbent gas components on the surface depends basically from two parameters – the temperature and the partial pressure of the deposited gas components, in this case CO_2. The dependency is represents that in case of cumulative temperature the loading is declining, against what the loading shoot up with the increased partial pressure.

These properties are exploited by the TSA process in the case of lower temperature to clean and by the higher temperature to regenerate the adsorbent. To boost the performance of the regenerator, so called strip gas (in form of steam or air) is used. With this process is the partial pressure of the removable components dropped and thanks to that also the loading reduces. The adsorption processes is exothermal, against to desorption which is characterized by an endothermal process. To obtain the necessary temperature cycle (temperature swing), which should be continuously heated and cooled, the decruited amount of heat from the adsorption should equal the amount of the energy which is required for the regeneration procedure by the desorption.

The concreteness of this TSA process bases upon the treatment of biogas to the quality of a natural gas. The biogas of the biogas in Strem consists of 50 – 65% of CH4, 30 – 40 % CO_2 and small shares of H2S and NH3. In the case, that this biogas is coming from the biogas fermentor, there has to be considered, that the consisting of water steam. Furthermore, to perform the biogas on a quality to be suitable for feeding to the natural gas, it should be desulfurized, dried and free of CO_2. To remove the CO_2 with an efficient way should be used the Temperature-Change-Adsorption. The research activities of the Technical University of Vienna in several research stations show, that the suitablest way for the porous silicon particle are the electroplated amin solutions. The adsorbent materials point out a high selection of CO_2- elimination, whereat the dynamic loading is possible up to 10% by weight. The adsorbent works a little bit over the environmental temperature by 50 – 70 °C and the regenerator by 100 – 120°C, at which the whole system is also operating at the environmental temperature. Necessary for an optimum performance is a gas-solid contact as well as an excellent thermal heat management. For a gas-solid contact instruments are foreseen the fluidized bed as for the adsorbent as for the regenerator, because the fluidized bed is suitable for both requests.

A realized technological-economic evaluation of the Technical University brings the results, that the described TSA process has a big potential. Furthermore, there was a research undertaken for the suitability of similar applications, directly at the TU Vienna, which also demonstrate the unique system.



Graphic 3: Schema of the TSA – product treatment

3.2 Economic effects

The energy revolution of ökoEnergieland was a process of many various small steps in different fields. Many of those partly revolutions were adapted and modified according to national and international basic conditions.

The next great aim of the ökoEnergieland is therefore to build up a local biogas grid to supply the region with thermal energy. For this a case study calculation were done with the result that the whole concept will have an investment up to € 52.000.000,-.

With a successful implementation of this biogas grid the ambitious aim of the creation of an energy self-sufficiency region could be realized. Moreover, as explained in the previous chapters, the implementation of a regional feedstock association is planned, the establishment of up to three biogas plants, biogas storage, biogas filling stations and other components should be built up, which all goes hand in hand with the building of a unique infrastructure network. All these components occurs new jobs, as well as more regional taxes which would help by financing of other projects in the region.

3.3 Environmental impact

In parallel to the implementation of the biogas grid also another project, called Regional Feedstock Association, is running. This project is an important component of the project biogas grid. The aim of the project is to establish an association, where the regional unused waste resources should be collected. The resources are categorized following:

- Marginal strips of goods paths (up to 1.000 km in ökoEnergieland)
- Riparian strips of water streams and graves
- Shrub, tree and vine cut
- Unused forest and agriculture fields.

That mentioned resources are yearly cut, but not more used and decomposed on the fields. Different analyses were made, where the results show that these resources consist of a big potential, which could be used either for a thermal or biological gasification.

The issue is of course, how to handle this materials and how to bring it out from the fields. Also for this problem fields a solution was find, where different types of machines were bought.

The aim is an intensive integration of the citizens into the resources logistic chain and furthermore to give them a possibility, to dispose their continuously incurred feedstock and to use it for a valuable energy production. The next aim, which is connected to this project idea, is to replace the wood chips and resources from the food industry with unused resources of the region. The regional feedstock association should be also the solution for the delivery, stock and supply of sources for the energy plants in ökoEnergieland.

3.4 Social benefits

The region of ökoEnergieland is going to made a fundamentally decision for its future, mainly based on the utilization of regional resources for the energy supply. This includes not only a creation of an added value in regard to new jobs, but also more independence from energy imports. Also around the core idea of a renewable energy supply an overall philosophy was developed, which will converted the region in a sustainable and positive way.

After the erection of this biogas grid insurance further stable energy supply for the ökoEnergieland should be given, not only in form of heat, but also in form of electricity, and fuels, depending of what is used.

Based on the different aspects which are coming up with the implementation of this project, also lot of opportunities for a creation the regional added value, jobs or even more settlements of new companies could be offered.

Additional, also areas of mobility should profit from the new initiatives in future.

4 Conclusions

4.1 Regional potential of the tested local options

A part of the assessment for this project idea was to developed a form of a model where aspects like financial planning's, framework conditions, funds, technical findings and solutions were taken into consideration and evaluated. In addition, the availability of the regional resources and the potentials were calculated to have an overview of possible feasibilities.

Based on all these results it has been attempted to identify potentials for implementation of a unique network in ökoEnergieland following the still existing model of self-sufficiency in Güssing. Now, there is the potential to cover the whole ökoEnergieland with renewable energy, which should occur of a new to new model region with typical energy related activities.

As already described the implemented model should focus on energy efficiency, recycling, utilization of unused resources, creating new local and regional jobs, increasing the regional added value, the long-term raw material security of energy facilities, creation of detailed basis of decision making for plant operators and users, the rapid and efficient construction of new energy plants as well as new unique models.

4.2 Follow-up plans

All technical findings and the overall activities, which were made in the course of **AlpStore** project also evoke new fields of renewable energy and its utilization. The plan is to build up a safety supply chain in the region, with an effectual energy amount for the supply purpose. Parallel to this, also a lifecycle oriented project for a sewage treatment plant should be implemented.

Meanwhile, there are different activities because of the framework conditions from the European Union, which don't allow the utilization of the sewage as manure for the agricultural fields anymore. This statement occurs big challenges for the sewage water treatment plants, because of the deposit of the sewage. It is combined with high logistic and transportations expenditures.

The solution could be, that a thermal gasification plant could be installed at the sewage treatment plant to gasified the output and use it as an input material for the gasification process. In that case, the produced energy of electricity and thermal energy could be obversely used for the process of the sewage treatment plant and the surplus of the energy in form of biogas or methane could be otherwise put into the existing biogas grid. This should be an added value not only for the sewage treatment plant, in a form of cost saving for the transportation, but also for the biogas grid as an additional quantity of energy.

4.3 Transferability to other Alpine regions

The model of self-sufficiency, which was developed in Güssing 20 years ago and the unique model of the local biogas grid which is going to be implemented in the next months are forced not only to increase the utilization of the renewable energy sources in the region but also to increase regional added value and to create new jobs.

Without all those initiatives around renewable energies the region of South Burgenland would have become a dying region. Therefore stakeholders and politicians are interested in new innovative projects. The supply of the region with biogas and the implementation of the local grid could be again such an innovative project. Especially as the pilot region is characterized by scattered settlements, which are not easy to supply with convential heating or district heating systems, this new technology could be an innovative chance.

As biogas plants are already under operation it could be seen as a perfect asset for them. Additionally different other advantages of a gas grid (cheaper in construction, no losses, …) has to be taken under consideration. If the implementation could be managed and financed during the next months we see a high potential for transferring this new technology also to other regions all over Europe. Especially Germany has problems with the efficiency of biogas plants and already raised interest to build up similar projects.

Aosta Valley Region, Italy
Smart Node
Case study

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Case studies are contributing to AlpStore WP6
Work Package 6 Responsible: EUROIMPRESA LEGNANO s.c. a r.l.
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1 Storage technologies for the Aosta Valley Region general frame conditions and objectives

The energy system of the Aosta Valley Region is closely tied to its peculiarities of differing nature, some purely geographical while others are connected to the socio-economic context. The Aosta Valley is characterized by small and very small municipalities, most of which are situated at the foot of the mountains and near large water basins.

The regional energy and environmental plans (PEAR), elaborated in the last 10 years, have always been directed at the development of electricity production from renewable sources and to the reduction of the internal consumption in order to keep - and possibly increase - the role of the Aosta Valley as a “green power station” for the electric system at national and European level.

Renewable energy sources such as, solar, wind, biomass and hydropower exist throughout the territory, the latter being, by far, the most exploited solution, covering more than 99% of electricity production, equal to 3.000 GWh/year. Notwithstanding the large amount of electricity produced, the requirement of the region is only a third, the remaining surplus flows towards the Italian territory and Switzerland through high/medium voltage lines; the actual destination of the energy flow on the high voltage line is not known.

Until now, because of RES penetration, the strengthening and enlargement of the distribution network already poses serious problems, linked to the natural environment and the technical or economic feasibility of new distribution lines. Moreover, the overall distribution grid efficiency, safety and reliability are challenged by the stochastic medium and low voltage connections of renewable power plants. This is a drawback for further exploitation of renewable energy, not permitting distribution at high levels of efficiency of the produced power. Furthermore, on a larger scale, the massive penetration of renewable power plants currently requires, other than a strengthening of power lines, the existence of fossil fuelled power plants which operates to guarantee the safety and the quality of the electricity service.

The introduction of energy storage devices (both stationary and mobile – intended as electric vehicles) within the power grid could provide a further degree of freedom for exploitation of the energy system, as this would permit to store part of the overproduction which can be used during high consumption periods. In addition, the stored capacity could replace the power safety and quality functions that are currently safeguarded by the traditional power plants. In the future electricity network the storage systems, in terms of energy on one hand and in terms of power on the other hand, represent a good opportunity for a smarter electricity system model.

Within the **AlpStore** project the Status Quo and the Master Plan reports findings and recommendations constituted the rationality for the development, the design and the implementation of the “Smart Node” Pilot Project. Starting from their findings the Smart Node model has been developed, which is a small-scale, distributed, low-budget energy management model. The Pilot Project wants to be as representative, replicable, easy to implement, and as effective as possible within the Aosta regional reality.

1.1 Actual and future regional energy system

The regional energy sector includes electricity, thermal energy and transport. The latest information is for 2011 and is included in the regional energy plan (PEAR) that is the official regional source where information on energy can be found. Within the **AlpStore** Master Plan some scenario for 2020 (taken from the PEAR) and for 2030.

1.1.1 Energy production

Because of the presence of large water basins within the Aosta Valley Region there are no conventional plants for electricity production (intended as plants fuelled by natural gas, coal and the by-products of oil) and no such plants for electricity production are planned. The conventional plants are limited to thermal energy production.

Hydropower is by far the most diffused method for power production from renewable sources in the Aosta Valley covering 99% of electricity generation equal to 3.000 GWh/year. The power plants' power range from some dozens of kW to more than 100 MW. Most of the plants are run-of-river installations with no significant storage capacity. There are 228 plants with a nominal gross annual power of 535 MW, corresponding to a gross effective power of 899.5 MW (source Terna, 2011). The hydro-electric resource has been, over the years, largely exploited and the residual potential is negligible with respect to what has been implemented so far. Because of the very high degree of exploitation of the water resource and the recent political and environmental trends the future production is considered equal to the present one.

Other RES offer a lower, but not negligible, contribution. The exploitation of the wind resource, that may be significant in some areas, is strongly limited because of technical, environmental and political constraints. In 2012 less than 3 MW of power was installed; in the 2020-2030 future the total power is estimated to remain below the 10 MW threshold.

In the Aosta Valley the photovoltaic potential largely varies from negligible to very remarkable productivity according to the morphological and atmospheric characteristics of the zone. The installed power has increased over the last few years due to national policies. The plants are characterized by their very small size, the majority of the installations are on buildings, mainly in the service and residential sectors. In 2011 in the Aosta valley 1116 PV power plants were installed with a total power of 13.9 MW. The production, that in 2011 was 11.1 GWh, in the PEAR scenario is assumed to rise to 48 GWhe/year by 2020 and to 64,2 GWh/year by 2030 (the latter being an assumption of the **AlpStore** master plan report).

The exploitation of biomass for heating and CHP has been strongly increasing over the last few years. In 2011 6.4 GWh of thermal energy from biomass fuelled CHP plants were produced, for total installed power of 4.5 MW. According to the data from the RENERFOR project, about 40% of small/medium firms uses biomass for heating, whereas in the civil field only 11.2% of houses exploits biomass as heating fuel for the main boiler; whereas, 36.3% of auxiliary boilers are fuelled by biomass. Some bio-mass fuelled industrial plants with district heating exist with a total installed power of 18 MWt. The diffusion of CHP plants and biomass power plants is expected to significantly increase by 2030.

The solar thermal installations regard domestic plants for domestic hot water production. Up until 2011, a total production of 12.16 GWh/year was assessed. In the future a constant increasing trend for the installations of about 2200 m2 per year is expected.

1.1.2 Energy Consumption

The overall energy consumption (thermal, transportation and electricity) of the Aosta Valley has been rising in the last few years and equals 6.000 GWh/year. Transportation covers 46% of the total, 36% is represented by the civil sector while 16% is due to the industrial sector (PEAR, 2008 data).

The electricity consumption is about 1.000 GWh. The industrial sector covers a great part of the total electricity consumption (44%), while the remaining part is divided among the service and household sectors (39%). The agricultural sector demand is irrelevant compared to that of the other sectors.

Thermal energy production for heating comes prevalently from fossil sources; with most consumption in the civil sector (about 2/3 of the total). The total thermal energy consumption for the Aosta Valley in 2011 was calculated in 2389 GWh.

The transport sector uses 45% of the total energetic consumption. This data is under verification and revision, as it appears over-estimated.

1.1.3 Regional Master Plan and Vision

The regional energy policy aims to improve the regional energy balance according to European and National directives and targets and to become a model region for energy and environmental sustainability. In this vision, the implementation of the STORM concept (Smart sTORage and Mobility, intended as a development model of holistic solutions to increase regional RES supply and outbalance volatility with appropriate energy buffering means) is seen as a completion and integration of the regional energy plan. The following storage related goals can be listed:

- To achieve the regional Burden Sharing objective 52% (ratio between the energy production from RES and the total energy consumption)
- To promote RES integration in the electricity system
- To investigate the application of the STORM model in the pilot region
- To promote widespread sustainable mobility (Electric Vehicles)
- To increase energy self-consumption
- To increase energy efficiency, stability and flexibility of the whole electricity system
- To support local enterprises which are active in the smart energy management sector.

The storage applications which are deemed as the most relevant within the territory, including the economic, ecological, social aspects and institutional affairs are the following:

- hydraulic plants pumping storage;
- distributed small size stationary storage units;
- low temperature thermal storage through the exploitation of the thermal inertia of buildings
- mobile batteries on electric vehicles.

The **AlpStore** Pilot Project focuses on the distributed small size stationary storage application and its system is named “Smart Node”.

1.2 Regulatory framework

1.2.1 Italian Framework

The management of energy production/consumption covers a central role especially in those power systems (such as the Italian one) with a huge penetration of non-programmable renewable resources. In this context, the stochastic power production from RESs requires suitable management of both the generation and consumption resources across the grid, in order to ensure the safe operation of the system (power balance) in all operational conditions. To this purpose several recent regulations and technical rules for the connection of DG power plants have been recently issued to set the basis for distributed monitoring of generation and load resources connected at the MV/LV level. New standards for quality of service have also been set. Following this direction some pilot projects for electrochemical distributed energy storage systems (batteries) have also been started.

Italian regulation makes clear the benefits which could be achieved through a widespread monitoring system on the MV/LV network. Equipping active and passive users with an energy management system able to exchange data in real time with the Transport System Operator/Distribution System Operator (TSO/DSO) will make the collection of data possible (e.g. power exchanges; voltage quality) useful for the operation of the network, and also for planning and for regulatory purposes. Despite the fact that currently DSOs are not required to dispatch the load/generation resources underlying their grids, in the future this service could be requested from them.

1.2.2 Valle d'Aosta Region Framework

Referring to the Aosta region local context no relevant policies concerning energy storage or smart grid have been issued. However the region itself has the legislative and administrative powers to issue plans and to establish mandatory requirements or incentive schemes. The main instrument is the Energy and Environmental Plan 2011-2020 (PEAR) The PEAR does not constitute an actuation instrument, but contains guidelines and useful indications. It describes, moreover, the target that the region should reach to be coherent with what is required in energy and environmental terms.

2 Pilot project Smart Node

The implementation of a small scale distributed energy storage unit has been considered as the most interesting and economically feasible application for the Aosta Valley territory. The Smart Node pilot action aims to optimize the energy flows of a small medium enterprise (SME), which represents a large extent of users in the Aosta Valley, not only those exclusively belonging to SMEs sector, but also to the residential and commercial sectors. Although small sized, a substantial penetration of the Smart Node system over the territory would imply a significant total storage capacity.

2.1 Characteristics of the field test

2.1.1 Choosing the implementation location

As previously stated the selected site well represents a large number of users, meaning that the pilot plant is suitable for reproduction and dissemination over the whole territory. The project idea has been developing taking into account the knowledge gained through the **AlpStore** project investigation phase. The Pilot site was finally established as the building where MAVEL Srl, the technological partner of the **AlpStore** project, is based. This solution presented several advantages in terms of system management, accessibility, monitoring and data analysis, making it easier to test a wider range of storage functions and configurations.

The site was also believed adequate as it assured lower uncertainties on times and costs of the implementation, a higher proximity to the technological sources and higher continuity of the monitoring. Figure 1 shows the installation site and components.

2.1.2 Purpose of the pilot

The Smart Node purpose is to test different storage functions and configurations in order to assess the performances, the benefits and the disadvantages of the system and to provide experimental data for mathematical simulation, which are run as a separate activity in the **AlpStore** project. Hence the pilot project aims to validate the Smart Node concept through the acquisition and analysis of the experimental data. Moreover the installation is expected to provide the designers some useful data for future development of the energy management system.

Technology

The Smart Node model is constituted by a RES generator, an electrical load, a storage system and an intelligent control unit for management and control. An electric vehicle (a mobile storage unit) has been inserted into the node as an additional load. Figure 2 describes the system architecture.

The smart control unit is partially embedded in the AC/DC converter that is connected to the network and is able to communicate data and react in real time to signals that come from others devices and a web data server. The device coupled to proper algorithms of control, manages the energy flows according to its objective function. More details on the components are given below:

- **N.1 Bidirectional inverter WQ E12.0:** it is a three-phase inverter with an integrated bidirectional DC/DC converter that predisposes the coupling with a storage system with a modular lead gel battery of 22 kWh. It is also equipped with an AC channel connected to the grid and to the local electricity user and with communication ports that connect it to other Smart Nodes as well as to a central control.
- **N.1 Storage System:** it is an electrochemical stationary storage system with a modular lead battery of 50Ah and a capacity of 22 kWh (useful capacity 10 kWh); maximum power of charge/discharge 10 kW-C1, with DOD up to 50%;
- **N.1 PV power plant:** a PV system composed of 44 modules of 250 kWp divided into two strings for a total power of 11 kW in DC and shelter support that allows it to integrate and interface in a smart manner with all the system components;
- **N.1 Smart Metering system:** different components dedicated to data acquisition and analysis useful for the remote monitoring, by means of ICT technology, the power flows circulating inside the Smart Node;
- **N.1 Electric Vehicle:** n.1 Renault Kangoo has been used as a company vehicle for the daily movements related to normal company activities.

The sizing of the components was designed in order to achieve a power ratio of 1:1:1 between the PV system, the average user's load and the useful energy of the storage system (it is worth noticing that MAVEL's maximum power load is about 50 kW, although this value is rarely reached).

Figure 1 –The Smart Node Pilot Project Building (above) the power converter and the storage (bottom left) and the PV system (bottom right)

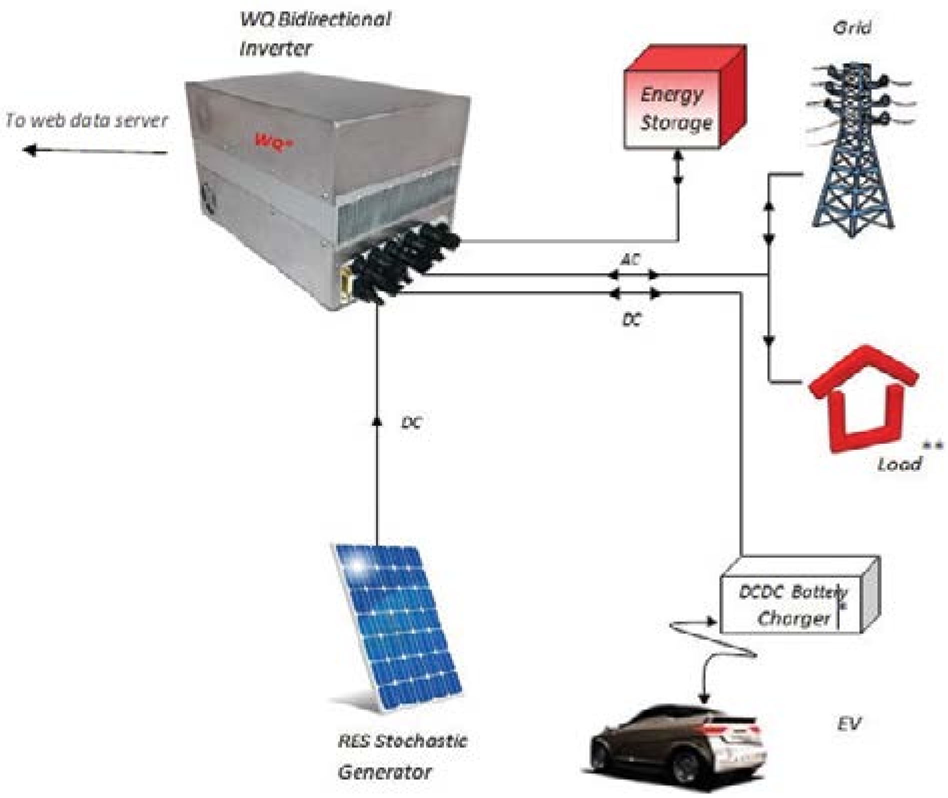


Figure 2 - Smart Node architecture

* In the Smart Node the EV recharge was achieved in standard AC mode

Objectives

The main objectives expected from the Smart Node pilot project are:

- to check "in the field" real implementation of different storage configurations and functions;
- to assess the main tuning parameters of the pilot energy system;
- to assess, on the basis of the experimental data and the simulation, the technical and economical performances of the node;
- to provide experimental data for the calibration and the validation of the numerical model used for the regional simulation activity;

Involvement of Regional Stakeholders

The main stakeholders are local energy producers, grid operators and the so called "Prosumers".

The largest regional energy producer is the **CVA Spa** company that owns more than 90% and generates about 99% of total electricity production. The regional grid operator is Deval Spa, which is responsible for the operation of the distribution grid and the quality and the safety of the electricity supply. **DEVAL Spa** operates about 4205 km of power lines in medium and low voltages and controls 13 HV/MV substations and at least 1519 transformers where the MV/LV passage takes place.

The so called "prosumers" are those users who are able to exchange with the grid a two-way flow of power. The most representative “prosumers” are residential users, small tourist activities such as hotels and B&Bs, offices and small commercial activities and finally SMEs. For the former, the most common size envisages a few kW of installed power and some MWh/year of energy consumption. For the latter, the power and energy consumption values may increase up to of one or two orders of magnitude.

Other relevant stakeholders are local public administrations, such as the municipalities, that may be strongly involved in the sustainable mobility sector, energy services companies and the local energy agency COA energia (Finaosta SpA).

Relevance for energy future in the region

In the very near future, following the regulatory and economic framework development, it may be possible to integrate the Smart Node model in the regional electricity system according to the user’s needs (e.g. maximizing energy self-consumption), the demands of mobility, but also in relation to the issues of safety and quality of service perceived by the network operator.

The vision is that RES generators, integrated with mobile and stationary storage systems will become progressively balancing elements of the grid from the bottom up, rather than being, as they are today, an element of disturbance. The more the diffusion of distributed storage is successful the more effective will its impact be. If adequately supported, the Smart Node will help to balance the grid in terms of energy and power; eventually leading to obvious improvements to the network itself and a benefit to consumers who will increase their rate of self-consumption or even become active players in the electricity market.

3.2 Storage technologies and frame conditions

The chosen storage technology is the electrochemical stationary type, with modular lead gel battery of 50Ahm a capacity of 22 kWh (useful power 10 kWh) a maximum power of charge/discharge 10 kW-C1, with a DOD up to 50%. Batteries for stationary application do not need to be light weight or small sized, capacity and total cost are the most important features.

The lead-acid battery storage unit was chosen since, thanks to the low cost, it currently has the largest market share and it is commonly believed that in the near future it will remain the most widespread technology for stationary application.

In Italy the principal electricity operators are involved in the stationary battery study. They are looking for different applications. Sodium-Sulfur NaS batteries and Flow batteries ZrBr and VRB are the kind of electrochemical storage systems applicable for energy intensive purposes. Power intensive storage systems are useful for adjustment in seconds or minutes: they need to constantly balance the energy production and consumption and maintain the grid stable. This is very important also considering that the increase of renewable energy production means a reduction in the operation of the conventional fossil plants and the primary power reserve connected with them (by law). Lithium ion Li-Ion batteries are the most interesting electrochemical storage systems for power intensive regulation.

It should be highlighted that, at the time the pilot project began, the national regulatory framework did not allow an electricity energy storage system to be charged directly from the grid (see the consultation document published by the Authority 613/2013/R/eel). This aspect has influenced the logics of control that were implemented in the Smart Node during the experimental phase.

3.3 Research design and schedule

The details of the activities undertaken from the very beginning to the end of the project are:

- Choice of target users;
- Analysis and selection of storage functions;
- Listing, evaluation and selection of suitable technologies;
- Definition of the Smart Node configuration;
- Realization of a numerical simulation model of the plant (done as an additional WP activity);
- Construction of the plant;
- Realization of the data acquisition system;
- Implementation of the system configurations and storage functions;
- Monitoring of the plant during its exercise;
- Validation of the numerical simulation model (done as an additional WP activity);
- Data processing, project results and reporting.

The pilot project ran and tested different configurations of the node; a configuration is a specific combination of node components as described below:

- *Load – Grid:* it allows to characterize the site before installation of the project components;
- *Load – RES – Grid:* this analysis highlights the benefits that may derive from the presence of a RES power plant by the user. In this way, the effects of the power generation are separated from those deriving from the presence of a storage system;
- *Load – RES– Storage – Grid:* it allows exploitation of the full potential of the node by managing the energy flows according to different operational logics. An EV is added to this configuration as a load; however, the recharge of the vehicle is managed depending on the storage DOD conditions;

Within the above configuration framework some specific storage functions have been selected giving priority to the energy intensive (rather than the power) applications and choosing the ones which were expected to have a higher value for the regional energy system. The following functions were tested:

I. *Self-consumption maximization:* the operation algorithm will maximize the self-consumption of the user, hence requiring minimum supply from the grid.

II. *Maximum load leveling:* the leveling of the node towards the grid is constituted by the smoothing of the load diagram through the management of the storage system in order to keep the power load close to a given set-point. It includes the management of the recharge priority of the EV.

The original pilot project time frame is reported in Table 1. However, in the field test, a relevant time mismatch from the planned activity to the real implementation occurred.

	15/12 2013	15/01 2014	15/02 2014	15/03 2014	15/04 2014	15/05 2014	06/07 2014	08/12 2014
Characterization and monitoring - Load – Grid								
Authorization procedures								
Purchase of the material								
PV plant installation								
Characterization and monitoring: Load – Storage – Grid								
Characterization and monitoring Load – RES – Grid								
Characterization and monitoring: Load – RES– Storage – Grid								
System monitoring								
Milestones		Authorization	PV plant purchase	EV purchase	Storage Purchase		Workshop	Final Event and reporting

Tab. 1 – GANTT

3.4 Implementation process

The Smart Node activities started from the load monitoring phase (Load-Grid). The user's load (current, voltage, power) was monitored for about two months with a three phase transducer with a sampling frequency of 60''. The data were sent remotely to a central server via GPRS and to a web platform from where it was possible to download or visualize them.

Although delayed because of some authorization issues, the second step (Load – RES - grid) was performed swiftly. The PV plant production was monitored for more than one month, before storage installation, performing smoothly. The PV size of 11 kWp was determined by technical and economic reasons.

The third step (*Load – RES – grid –storage*) was implemented by installing the storage system and uploading the algorithms of control and running them in the Smart Node. Except for storage positioning and wiring, all the activities were performed via software by remote. During this phase an electric vehicle (i.e. a Renault Kangoo) was used by MAVEL as a company vehicle. A recharge management system was set up in order to alert the user when a surplus of energy was available for the recharge.

Barriers to overcome

The main barrier to be overcome was constituted by the lack of technical regulations for direct recharge of the storage system from the grid. Technically it would already be possible to implement this function.

Deviations in objectives and timescale

Some of the storage functions considered in the design phase, such as cash flow maximization (that considered the energy market price maximizing the differential cash flow of the user) and load/ production management (that implies the forecast of the energy production and consumption and the respect of a power diagram) could not be tested because of the inhibition of direct recharge from the grid.

The terms of the project activity, expected in the time plan of the implementation plan have been postponed of several months due to authorization delays.

Factors affecting the pilot actions during application

There weren't any particular actors observed that affected the pilot actions during application. The user's site activity and business continued as usual.

3.5 Simulations

The Smart Node quantitative findings are, to a certain extent, limited by the seasonal variation of PV production and the limited time period in which the pilot project was run. The extension of the experimental data over the whole year was possible through the use of a mathematical model which can simulate the Smart Node operation for a longer period and under different conditions.

Although the simulations were carried out as a separate activity within the **AlpStore** project, the findings deemed as relevant for the Smart Node project are included in this report.

4 Main outcomes and benefits

4.1. Technical Findings

4.1.1 Load - Grid Configuration

The SME's load in a working day is showed in Figure 3. The power profile rises between 8:00 and 17:00 and is characterized by peaks of power which happens with a regular frequency of about 30'. The peaks are due to the presence of two air compressors (5 kW each) which are turned on automatically to keep the pressure of a pressurized air reservoir above a set-point value. The average power employed by the SME is around 10 kW.

During non-working days the requested power decreases remarkably down to an average value of 1,6 kW and a base load of 1,1 kW (Figure 4). The power peaks caused by the air compressor engines still occur briefly increasing the load up to 10 kW.

Fig. 3 – MAVEL's power load, working day

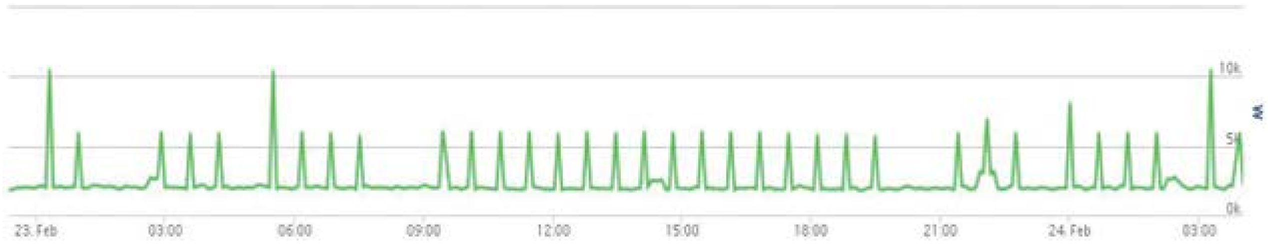


Fig. 4 – MAVEL's power load, non-working day

4.1.2 Load-RES-Grid Configuration

The installation of a 11 kW PV power plant on the pilot site can assure a yearly energy production of about 12 MWh; however, the actual user's self-consumption rate depends on the size of the PV plant, the storage capacity and the load profile over time. In Figure 5 the load profile of a working day with good irradiation is shown.

After the PV installation average power absorbed from the grid by the user decreased from 10 kW to 5 kW. Moreover, with the exception of some days, in which some power was fed into the grid during the evening (typically during summer days after the end of MAVEL's activity), in most cases almost all the energy produced during the day was immediately self-consumed. Generally speaking, the percentage of consumption depends on the size of the generation plant, the capacity of the storage system and the load profile of the user. In the case the former is much lower than the load is reasonable to record a high percentage of self-consumption.

Table 2 reports the comparison of the data the F1 time slot (from 8.00 to 19.00, from Monday to Friday), of the five working days in a week with the PV plant (week 09/03 – 13/03) and without the PV plant (week 14/07 – 18/07). As already mentioned the self-consumption average rate is extremely high and, in this period, equal to 98.5%. The average power absorbed from the grid was reduced by about 50%, passing from a value of 11.3 kW to a value of 5.2 kW.

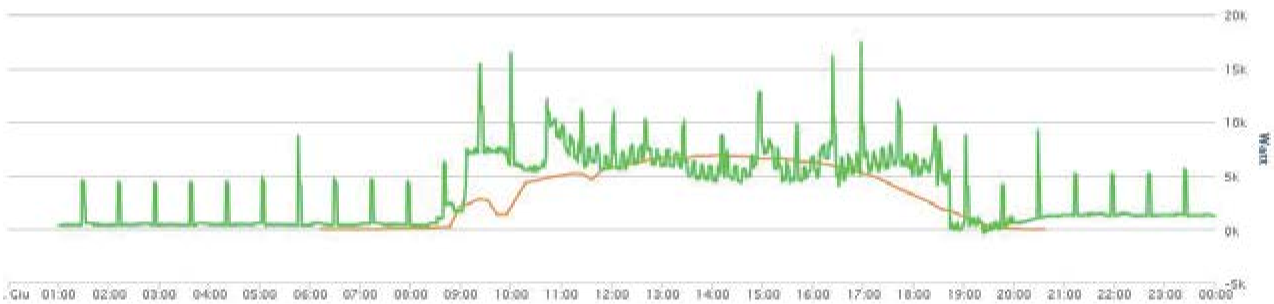


Fig. 5 –Power profile at the interface with the grid (green) and power generated by the PV plant (red)

Smart Node in configuration LOAD – GRID (week 09/03 – 13/03)		
MAVEL average load	11,3	kW
Average Energy absorbed from the grid	121,4	kWh/day
Smart Node in configuration LOAD - PV – GRID (week 14/07 – 18/07)*		
MAVEL average load	9,1	kW
Average Energy Consumption	100,76	kWh/day
Average power at the interface with the grid	5,2	kW
Energy absorbed from the grid	56,76	kWh
Average power generated by PV	4	kW
Average net energy generated by PV	44,00	kWh
Average Energy self-consumed	43,35	kWh
Average Energy input in the grid	0,65	kWh
Self-consumption average rate	98,5	%

Tab. 2 –MAVEL energy statistics

**** During the week 14/07-18/07 the MAVEL average load was slightly lower than that of the week considered in the configuration LOAD-RES-GRID from 09/03 to 13/03. This variation is due to the different working cycle of the site.***

Although the maximization of the self-consumption rate is surely an option it still poses some limitations in terms of power volatility towards the grid and concerning the overall quantity of energy that can be self-consumed (meant as an amount in the long term, and not as a ratio, of energy that is self-produced and self-consumed). In fact Figure 6 shows that during non-working days a large amount of energy is fed into the grid, resulting in a low value for both the user and the energy system. In order to increase the user self-consumed energy without affecting the grid operation the introduction of an adequately sized storage system is required.

Fig. 6 – PV power generation (red line) and grid interface power (green line) of a non-working day with good solar radiation

4.1.3 LOAD – RES – STORAGE – GRID: Self Consumption Maximization

The 22 kWh lead-gel storage system was first run with the aim of increasing self-consumption by storing the self-produced energy during overproduction periods and feeding it to the user instead of taking energy from the grid.

Within the pilot project a significant improvement of the quantity of self-consumed energy was observed during non-working days. Figure 7 shows the power profiles at the grid interface (in green), the active power (in orange), given by the sum of the power produced by the PV plant (always positive) and the power of the storage system (which can be positive when the battery is discharging or negative when the battery is charging), referring to Saturday 23/08. The orange dashed line represents the power generated by the PV plant (calculated on the basis of the battery charging power).

Fig. 7 – Power profile of the Smart Node in configuration Load-RES-Storage-Grid

As clearly shown in Figures 8 and 9 part of the energy produced by the PV plant was absorbed by the storage system (areas in red). The battery current is negative when charging and vice-versa.

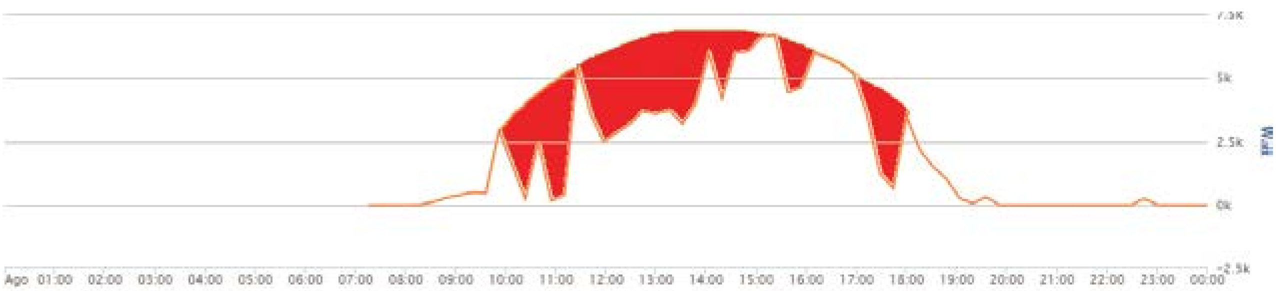


Fig. 8 – PV energy stored in the battery (red area)

Fig. 9 – Battery Current Profile during the day

The irregular profile of the re-charging of the storage system is mainly due to the load peaks of the air compressors, which cause a rapid inversion of the flow with respect to the grid (there is a passage from a phase of energy input into the grid to a phase of energy absorbed from the grid); consequently, the storage system, which was charging trying to limit the energy input to the grid, with a sudden energy request from the user, interrupts its re-charging cycle giving priority to the self-consumption. In this specific case, the delay of the system (with particular regard to the communication one) does not allow the storage to feed power to counterbalance the peak demands, as these are too short. Considering this day as representative for a non-working summer's day, it can be observed that a maximum of about 27% of the energy generated by the PV plant has been stored in the storage system, avoiding input into the grid, as reported in Table 3. This value actually corresponds to the battery capacity limit.

Smart Node in configuration LOAD - PV – STORAGE Max self-consumption		
Energy generated by PV	43,9	KWh
Energy stored in Battery	12,2	KWh
Energy Input in the Grid	31,7	KWh

Tab. 3 – Max self-consumption statistics – non working day

The algorithm performed correctly. When some surplus of energy was available, the storage recharged, storing part of the RES power. This mainly occurred in the non-working days when the storage capacity was completely restored by the PV panels and, to a certain extent, during the evening of the other days. The node also correctly exploited the stored energy whenever the load was greater than the energy production and the energy in the batteries was available.

The above situation is representative for a non-working day with a good irradiation, however, considering a longer period, it can be stated that, from a quantitative point of view the size of the components (generation and accumulation) has restricted the influence of the energy management system in the overall energy balance, this just because other no energy surplus was available or the batteries were already fully charged.

Storage efficiency rate

Interesting experimental data collected from the pilot project was the average storage efficiency rate. The rate was calculated as the ratio between the energy output and the energy input for two representative cases. First, a complete charge/discharge cycle of the battery was considered (period from 10:50 h of 14/8/2014 to 10.22 of 15/8/2014). The calculated value of the global battery efficiency was:

$$\bar{\eta}_1 = \frac{(\text{Output energy [kWh]})}{(\text{Input Energy [kWh]})} = \frac{11{,}30}{13{,}06} = 0{,}865$$

Corresponding to a single charge and discharge process efficiency equal to 0.865 1/2 = 0.93 (93%). The second case considered a day with different and more severe operative conditions (from 11:10 h of 15/8/2014 to 10.35 of 16/8/2014). The calculated average efficiency was $\bar{\eta}_2 = 0{,}802$, from which an average efficiency of charge and discharge equal to 0, 89 (89%) can be derived.

An average value of 83,3% for the lead-gel battery technology can be assessed. The experimental data are consistent with the information from literature which highlights values comprised in the range 82%-90%. Figure 10 shows the voltage and the current profile of the storage system for the first case calculation.

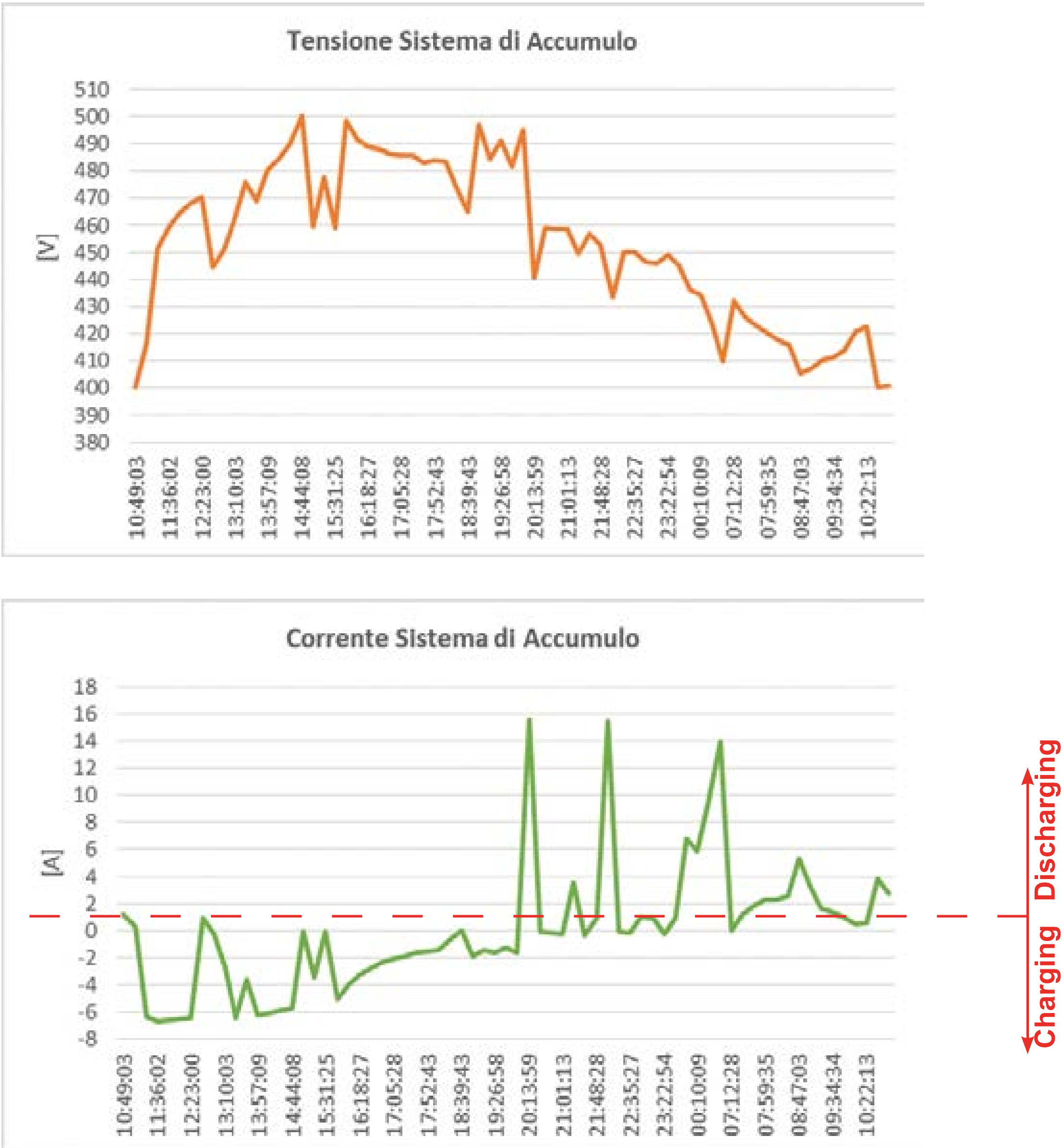


Fig. 10 – Voltage and current profile of the storage system

4.1.4 LOAD – RES – STORAGE – GRID Maximum Load Leveling Function

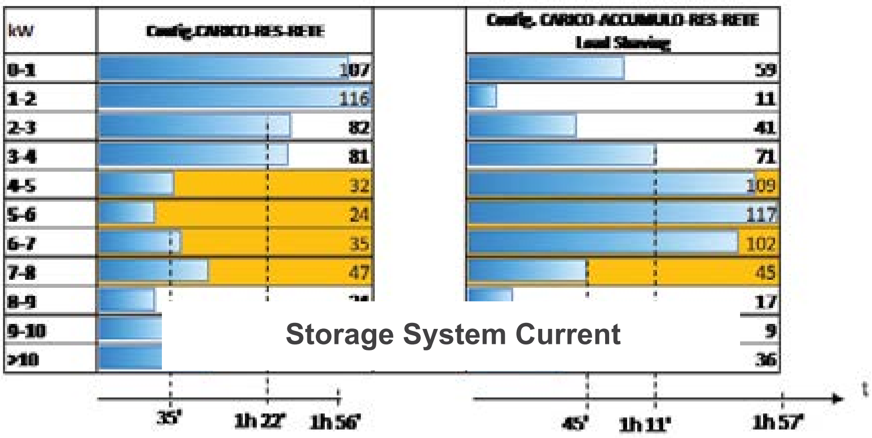
The *Maximum Load Leveling function* keeps the power value at the grid interface close to a set point of 5kW for the longest possible time during the day. The threshold value accords with the average power load taken by MAVEL from the grid in a working sunny day.

In order to check the algorithm performances a comparison between two days with a very similar user's load and PV generation profile was made (day: 17/07/2014, average load 8,84 kW, PV average power: 4,25 kW; day 29/09/2014, average load 8,02 kW, PV average power: 3,6 kW).

Considering the F1 time zone (8.00 – 19.00), on 29.09.2014 the power was kept between 4-8 kW for almost 6h30', while, as we can see from the table below, in the other case, without a storage system, the power was kept between 4-8 kW only for 2h18' (the latter value was calculated from the storage voltage data).

Storage System Voltage

From the grid point of vie.. ..ne algorithm created a benefit by limiting the power fluctuations and smoothing the distortion induced by the photovoltaic stochastic generation and user's load volatility. It is worth highlighting that the quantitative performance refers to the summer period and can't be directly extended to the rest of the year. Table 4 shows the power ranges and the time length for which the load was kept in the corresponding range.



Tab. 4 – Maximum load levelling statistics

4.1.5 Electric Vehicle Recharge Management

EV recharge management was constituted by an e-mail alert that was sent to the user every time an energy surplus occurred. During the experimental phase of 30 days over 50 e-mails for recharge priority were sent. It was calculated that an additional energy self-consumption of 10%, for the EV re-charge during non-working days could have been achieved.

4.1.6 Simulations

The simulation activity investigated the impact of the Smart Node penetration into the grid on a system level. For this purpose a grid distortion factor D, defined as the peak power excursion in the monitored period, divided by the mean power in the same period, was introduced. The simulations run the Smart Node functions extending the time period (therefore accounting for the seasonal variations) and performing a sensitivity analysis for some parameters.

Generally speaking the dissemination of storage devices to a certain number of the users caused a reduction of the grid distortion factor both in the maximum-self consumption and in the load leveling mode. Depending on the considered mix of users (i.e. residential and/or SMEs) the benefits ranged from -30% to – 8% in term of distortion reduction.

This means that the grid would be able to host some extra RES power, such as PV panels, and to counterbalance the RES side effects by a correct storage operation. Moreover the extra RES power would also be able to compensate for the increase of the user energy consumption due to the storage efficiency.

More specifically, starting from the experimental data, the analysis considered a SMEs load profile in combination with different configurations of storage and PV systems size. The results showed that an application such as the Smart Node project could allow the introduction of about 3 kW of new RES in the energy system under “equal conditions” for the grid (with the term “equal conditions” meaning without affecting the grid distortion factor). Considering the PV technology production and deducting the storage efficiency, the 3 kW RES plant corresponds to 1.800 kWh of green energy for the system). Further details on the simulation activities and calculations are provided in the simulation report.

4.2. Socio-Economic effects

With the maximum self-consumption function operation the economic savings given by the storage system for the user were assessed to be about 234 €/year, that corresponds to 1.315 kWh stored over the year. These results were obtained starting from an electricity cost of 216 €/MWh and a remuneration of the electricity delivered into the grid of 38 €/MWh (PUN “Unique National Price”).

As previously described, considering the “energy intensive” function and the size of the PV and storage system (the latter being small compared to the energy consumption of the user) the influence of the storage system in absolute terms has been rather limited. Nevertheless the lead-gel technology being the cheapest on the market, with a current value of about 400 euro/kWh with-out power electronic, the pay-back time of the investment cannot be calculated.

Beyond the user’s perspective, other economic benefits are expected for the local DSO and the overall electricity system. They include the decrease of distribution losses, the deferral of grid investment, the increase of load capacity and renewable energy integration, plus different safety and quality functions which can be performed by battery storages.

The introduction of the Smart Node model in the regional energy system also opens new perspectives not only for the users, but also for practitioners and enterprises. There will be a need for technicians and ESCOs to design, install and maintain the systems, but also to manufacture the components and put them on the market. High technology SMEs like MAVEL/Whiteqube could lead the way and generate positive socio-economic impacts on the territory.

In this scenario a drawback for energy traders would be the reduction of the traded electricity however, the magnitude of the case will be, in most of cases, of a minor relevance. Finally from the regional energy system perspective the penetration of Smart Node will positively increase regional self-sufficiency.

4.3. Environmental impact

The main environmental benefits of the Smart Node project come from the opportunity to increase the penetration of RES in the system, without affecting grid conditions, hence improving the overall system efficiency.

The improvement of the system’s efficiency will also be caused by different factors, such as the decrease of transport and distribution losses, or the reduction of traditional power plants running in idle mode for safety and quality reasons.

Eventually it is worth noting that lead-gel technology is nowadays fully recyclable.

5 Conclusions

5.1 Regional potential

The Smart Node project, that is a small-scale system for distributed energy management, is aimed at a wide group of users, especially the commercial, residential and SME sectors. In consideration of the fact that consumption of the residential and commercial sectors on their own reach 39% of the regional total, it can be assessed that the theoretical technical potential of the Smart Node model interests an energy quota equal to 364 GWh/year.

Although the pilot action was undertaken by a single user, it can be easily replicated and extended across the territory. The logic of energy flow management has shown that, if correctly implemented, they can generate benefits for the users, the grid and the system. The performance indicators measured, in particular in the case of the electrochemical storage system, are the same as those seen in specialist literature on the subject. The experimental data collected were used to validate and calibrate the mathematical model used for the simulations and the construction of the diffusion scenarios for the Smart Node model in the local energy system. The simulations highlight, at a qualitative level, significant advantages in terms of grid management and integration of renewable energy production systems.

Further details on the energy and environmental impacts linked to the use of storage systems in the regional electricity system are supplied in the report on the simulations in the Aosta Valley

5.2 Future development

The future of Smart Node application is concentrated on research aspects regarding understanding of the behaviour of the system; this will come about through continued monitoring of the pilot plant by MAVEL. The most interesting aspects are:

- the effect of seasonal variation on the performance of the Smart Node;
- the influence on the electricity grid with the presence of one or more Smart Nodes;
- the test regarding the different functions of the storage systems, especially for those "power intensive" systems;
- the optimisation of the functioning of this technology and the evaluation of the performance of the system considering the ageing of the components.

5.3 Transferability to other Alpine regions

Implementation of the Smart Node project and the methodology adopted can be technically extended to other regions belonging to the Alpine Space and also to a wider number of cases. The technology for storage systems and energy management is now available on the market and it can be easily implemented anywhere in Europe. Extreme importance must be given to the project design and the sizing of the system according to the type of RES and the load profile of the user.

Region Gorenjska, Slovenia
PV_REDOX
Case study

University of Ljubljana
Faculty of Electrical Engineering

Project Partners: RDA-BSC Business Support Centre Kranj / University of Ljubljana, Faculty of Electrical Engineering
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Case studies are contributing to AlpStore WP6
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1 Storage technologies for the region Gorenjska - general frame conditions and objectives

Planning and operation of electric power system has been since its inception marked by the fact that electricity cannot be stored in a sufficiently large scale in an economical way. Therefore, the electric power system with all the primary components and the superior control systems must operate in such a way that the production can follow the ever changing load. Major efforts have been therefore devoted to the development of technology and control algorithms, which today allows stable operation of the system; however it still sometimes happens that the imbalance between the production and the consumption causes blackout.

1.1 Storage Requirements

In most countries, energy storage technologies are part of the SmartGrid concept, however development priorities of individual SmartGrid topics and the introduction timeframe for various technologies can be quite different from country to country. Among other, it depends on the natural resources and the specifics of the power grid.

The EU market for large electricity storage systems (e.g. PHPP) recently slowed down due to the fact that the demand for electricity from conventional power plants that cover the need for electric energy in trapeze and at peaks in the daily diagram, decreased (due to production from renewable energy sources - solar, wind) and therefore the differences between the highest and lowest prices at the European electricity market are lower than ever before. Because prices generally reached very low values (e.g. 3-4 cent / kWh), the investment in new capacities for storing larger amounts of energy and sometimes even the continued operation of the existing systems is not profitable.

An exception to this general trend is the emerging market for batteries in photovoltaic systems that enable greater self-sufficiency to owners of these plants. This segment developed due to the fact that in some countries the prices of electricity from small scale solar power plants have achieved lower values than the tariffs for households.

There is also a small market for energy storage systems to compensate peaks in the daily diagram. For example, some biogas plants that have sufficient storage capacities for biogas, heat and electricity co-generation, which gives them the flexibility, can be competitive in the market of balancing power.

At present, the market situation does not encourage mass deployment of electricity storage technologies, but if the growth in the share of production from renewables will continue at the same pace as in recent years (especially photovoltaic systems), large storage systems will become necessary very soon. Production from conventional sources will have a smaller contribution to the daily diagram (especially in the middle of the day when the output of a PV is at maximum), power generation from hard coal and lignite will be reduced, and the production of gas fired power plants will increase. Due to the increasing uncertainty of production capacity, the need for short-term and long-term storage of energy will become more and more pronounced, if we want to maintain the present levels of reliability and quality of power supply. Various foreign studies have shown that the increased need for energy storage and other ways of ensuring flexibility in power supply will occur, when the share of electricity supply from renewable energy sources becomes greater than about 50 %.

In Slovenia, market conditions and trends are similar to this general situation - the mass deployment of storage systems is still not profitable. Due to the relatively low price of electricity for households and subsidized feed-in tariffs for energy from renewable sources, the introduction of battery systems to provide self-sufficiency is currently not profitable.

Exceptions are the customers in remote areas, where there are frequent interruptions in the electricity supply. At this local level there are opportunities for a wide variety of actors, investors, regional energy agencies and local authorities. These options are non-regret, because they can be implemented in a short time without the risk of committing a big mistake if the development of electricity production from renewable energy sources, energy storage technologies, and the development of policy and legal frameworks takes a different path than currently expected.

1.2 Actual and future regional energy system

Smart grids that are key element of the future power systems represent third large investment cycle of the power system. The concept of smart grids is an upgrade of the existing concept of operation and design of the power system. It effectively involves the individual elements of the system, both classical (centralized large scale production units, transmission and distribution networks) and new elements, such as the distributed production resources, advanced measurement systems, flexible prosumers, virtual power plants, electric cars and energy storage systems.

The key are information and communication technologies that link all elements in the system into a functional whole. Existing information links are primarily between the operators and centralized production units, in the concept of smart grid it is necessary to establish a connection with the final information system users (customers, manufacturers or their distributed sources) and other elements of the system, such as the energy storage and infrastructure for electric cars. Information technology (IT) will play an important role and it will provide IT support to all processes within the concept of smart grids [1].

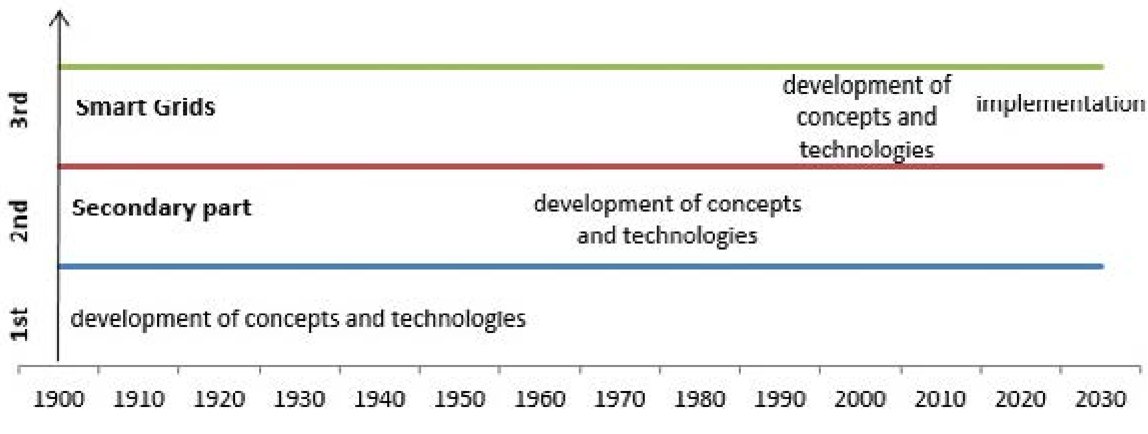

Figure 1 - Power system development stages [1]

The key document for future development of the Slovenian energy system is the National Energy Programme of the Republic of Slovenia for the 2010–2030 (NEP). Currently Slovenia is conducting a public consultation of the draft version of the document. The document follows European and International obligations for the Republic of Slovenia. Slovenia has to fulfil national and international targets regarding energy efficiency, renewable energy sources and greenhouse gas emissions, which are also main goals of the NEP.

The targets which have to be fulfilled according to the NEP are mainly determined by the EU climate and energy package, which is focuses on measures to increase the use of RES and energy efficiency. The goal of the climate and energy package is the development of sustainable energy supply systems with less greenhouse gas emissions.

On the national level, Slovenia is strongly focussing on the long-term exploitation of nuclear energy. The key measures in the NEP proposal are the extension of the operational lifetime of Krško NPP and the construction of a new nuclear power plant, Krško NPP [20].

Below is a short overview of the new National Energy Program (2011+) [3].

Long-term goals:

- To double the cogeneration capacity by 2020.
- Increase energy efficiency for at least 20 % by 2020 and 27 % by 2030.
- Renewables share in final energy use 25 % by 2020 and 30 % by 2030.
- Reduction of greenhause gas emmisions for 9.5 % by 2020 and 18 % by 2030.
- Reduction of energy intensity for 29 % by 2020 and 46 % by 2030.
- Have 100 % energy neutral buildings among new built and renovation in public sector by 2018 and elswere by 2020.
- Limit energy dependence on imports to less than 45% by 2030.
- More international / regional interconnections.

1.3 Regulatory framework

The key elements of the support environment in Slovenia up to 2020 are as follows [4, 11]:

- economic incentives (continuing the established scheme of support for generation of electricity from renewable sources and high-efficiency cogeneration of heat and power, with the preparation of a similar scheme for heat), direct financial stimuli and appropriate tax policy;
- regulations for methods of heating and cooling (introducing a compulsory share of renewable sources of energy in district heating systems, updating regulations for the use of renewable energy sources in buildings);
- improved planning: stepped up preparation of the expert basis for the physical placement of renewable energy sources on the national and local level; checking the possibility for improving administrative procedures for carrying out investments and checking the effectiveness of procedures through demonstration projects;
- a system of quality management in planning and implementing projects and of biofuel quality;
- incentives for developing financial markets and a range of appropriate financial mechanisms;
- support for establishing a wood biomass market;
- measures in the areas of education and training, research and development and promoting the development of industrial production for renewable sources;
- systematic promotion of best practices of efficient energy use and renewable energy sources, and ensuring high-quality information for evaluations involved in all decisions relating to the use of RES.

The main legislative documents in the Slovenian energy sector are the Energy Act [4] and the Resolution on the National Energy Programme [5]. These documents include all the guidelines for the energy development that were also partly outlined in the EU directives (e.g. 96/92/EC).

Energy Act

The Energy act is the main act in the energy sector establishing common rules relating to its organization and functioning. It also defines the basic structure of the system operating instructions that shall regulate the operation and the manner of management of transmission and distribution networks for electricity.

National Energy Programme

The Resolution on the National Energy Programme (NEP) was adopted by the National Assembly in April 2004. The National Energy Programme lays down long-term development goals and strategic guidelines for energy systems and energy supply, investments in public infrastructure, incentives for investment in renewable energy sources and efficient use of energy, the utilisation of economically justified technologies for the extraction of fuels and the generation of energy, and the anticipated extent of investment by private investors in energy-related activities.

TSO

Decree on the method for implementing public service obligation relating to the activity of transmission system operator in the field of electricity

The Decree [6] lays down the rights and obligations of the provider of the public service of transmission system operator, the organization of the public service, the manner and conditions of providing required services, the rights and obligations of the customers and means of financing.

Instructions on the systemic operation of electricity transmission network

The Instructions [7] lay down the instructions for the transmission network operation and conditions for electrical energy transmission from producers to customers. Minimum requirements for operation of interconnected networks set by UCTE and ETSO are also enclosed. These Instructions incorporate rules for customer connection to the transmission network and do not directly address distributed generation.

DSO

Rules on the system operation of electricity distribution network

The Rules [8] stipulate technical and other requirements for safe operation of distribution networks with the aim to provide reliable and quality energy supply. These Rules lay down the rules for systemic operation of the electricity distribution network, the duties of the distribution network operator, the terms and conditions for customer connection to the distribution network and define ancillary services of the distribution network.

Decree on general conditions for the supply and consumption of electricity

The Decree [9] determines the requirements and procedures for customer connection to the network. It also stipulates the network operator obligations regarding reliable and quality energy supply. The customer is required to obtain an approval for each individual connection to the network. In the Approval for Connection the customer connection point, the transferred power, the short circuit power at the connection point, etc. are defined. The customer energy facilities and installations must meet the requirements of technical standards and regulations to prevent disturbance of other customers. If the customer disrupts energy supply to other users, the operator can disconnect this customer. The Decree defines protective devices required for small energy sources. In the field of the quality of energy supply the network operator must observe the limits defined in the **SIST EN 50160** standard (**EN 50160**). The maximum number and duration of short and long term interruptions are also defined.

Decree on the requirements to be met for obtaining the status of a qualified electricity producer

The Decree [10] defines the types of qualified producers and establishes the requirements and procedure to obtain the status of a qualified electricity producer. The status is given to electricity producers that use RES and those who produce electricity in facilities of cogeneration at above-average efficiency.

Other relevant legislation

The Energy Agency issues the **RECS (Renewable Energy Certificate System)** certificates for the electricity produced from RES since 2004.

Any producer that produces electricity from RES, or in the process of cogeneration, can apply for a guarantee of origin of electricity. The process of issuing guarantees is still being developed.

The Energy Agency prepared the **Act Regarding the Mode of Determining the Shares of Individual Production Sources and the Mode of Their Presentation** that came into force on 1st January 2006. Suppliers of electricity to end users are obliged to publish (on the electricity bills and in promotional materials) the shares of individual production sources within the whole structure of electricity production. They are also obliged to include at least the URLs of web pages or details of other information sources, where it is possible to obtain information on the influence of the production-source structure on the environment.

2 Pilot project Trojane - PV_REDOX

Trojane is a small village in Slovenia, where a PV_REDOX pilot project was implemented. Vanadium-redox flow batteries were installed next to the Trojane restaurant, well-known for their delicious donuts that are prepared using nature-friendly energy from a PV source. Part of the pilot project concept was also an EV charging station at the restaurant location.

Figure 2 - Trojane restaurant

2.1 Characteristics of the field test

Choosing the implementation locations

Municipality of Jezersko was first choice of the remote alpine village that can be used as a test case for system operation, but because of severe natural catastrophe that happened in this village, we had to find a different location. There are of course several mountain villages in the Gorenjska region, however situation in the Jezersko is in certain aspect most critical. Below is a short description of the problem that was key factor for pilot implementation.

Location for the pilot implementation

Installation of the system in Trojane allows us to investigate key operational characteristics of the system, which will demonstrate the benefits of installing it in the remote areas of the Alpine Space. One example of such area is the municipality of Jezersko, Gorenjska, Slovenia, that was used as a "benchmark test case" of the system operation. Namely, system is operating in Trojane, but all the operation scenarios are transferable to other remote locations in the Alpine region.

The problem of electricity supply of the remote alpine areas – Jezersko example

Jezersko municipality is supplied by a long (radial) overhead distribution line, which is powered from the 110/20 kV Primskovo, feeder Britof Oljarica. As the line in the Kokra valley is heavily exposed to the external influences (trees, snow ...) that are causing short-circuits on the line, short- and long-term power supply interruption are more often than average. Continuity of supply is specified with the statistical indexes SAIFI and SAIDI. According to the Elektro Gorenjska indexes for Britof Oljarica specifically differ from the other indexes of the Primskovo (source: Elektro Gorenjska report on the quality of supply 2011).

Options for improving the reliability of supply are:

- construction of new MV lines,
- replacement of overhead lines cable conduits,
- energy storage backup during outages.

Because building or replacing existing distribution lines is more and more unacceptable by the local communities, energy storage technology could be a promising solution.

		MAIFI [prek./odj.]		
RTP/RP	Izvod	Izvod	RTP/RP	Podjetje
RTP_PRIMSKOVO	PRI_20_INTERSPAR - Mestni	0	0	0
	PRI_20_JAKA_PLATIŠA - Mestni	0	0	0
	PRI_20_PRES_BRIG - Mestni	0	0	0
	PRI_20_ŠUCEVA - Mestni	0	0	0
	PRI_20_FARMA_HRASTJE - Podeželski	4,615	0,201	0,031
	PRI_20_GOR_TISK - Mestni	0	0	0
	PRI_20_JEZERSK_CESTA - Mestni	5,107	0,157	0,024
	PRI_20_KOMUNAL CONA - Mestni	0	0	0
	PRI_20_GORENJE - Mestni	0	0	0
	PRI_20_IBI - Mestni	0	0	0
	PRI_20_ŠENČUR - Mestni	0,067	0,006	0,001
	PRI_20_VIDMARJEVA - Mestni	0	0	0
	PRI_20_BRITOF_OLJAR. - Mešani	31,345	6,239	0,962
	PRI_20_DEZMANOVA - Mestni	0	0	0
	PRI_20_KOTLARNA_PLA - Mestni	1,002	0,075	0,012
	PRI_20_MERKUR - Mestni	0	0	0
	PRI_20_VISOKO_BRNIK - Podeželski	8,826	0,858	0,132
	PRI_20_VRECKOVA_PLA - Mestni	1,936	0,221	0,034

Table 1: Number of interruptions per customer in 2011 (source: Elektro Gorenjska)

PV_REDOX technology

For the energy storage system, two Imergy's ESP4-5-20 units were installed next to the Trojane restaurant. The two storage units operate in parallel to other loads, on the same feeder as PV source and EV charging station. This configuration is optimal in terms of energy flows and operating conditions. Key technical characteristics of the ESP4 unit are given in table below.

Table 2: Technical characteristics of the Imergy ESP4 battery

Average Output Power	5 kW
Support Capacity	20 kWh
Peak Power	5.25 kW
Cycle Life	Unlimited over 5-10 years
Discharge Time	> 4 hours with 5kW load
Charge Time	< 4 hours with charge power of ~9kW
Charge Voltage Range	55 VDC ±3 VDC
Output Voltage Range	49.5 VDC ±1.5 VDC
Monitoring	Integrated Imergy Comm System (DCS), SMS, GPRS, RS232

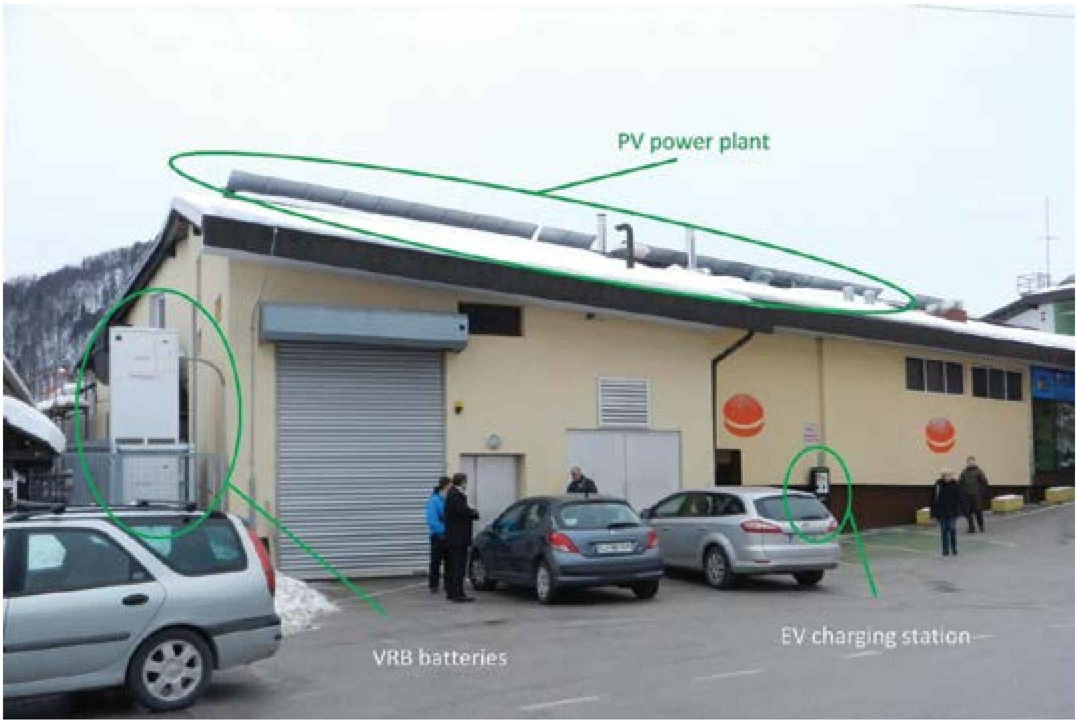

Figure 3 - PV_REDOX set-up

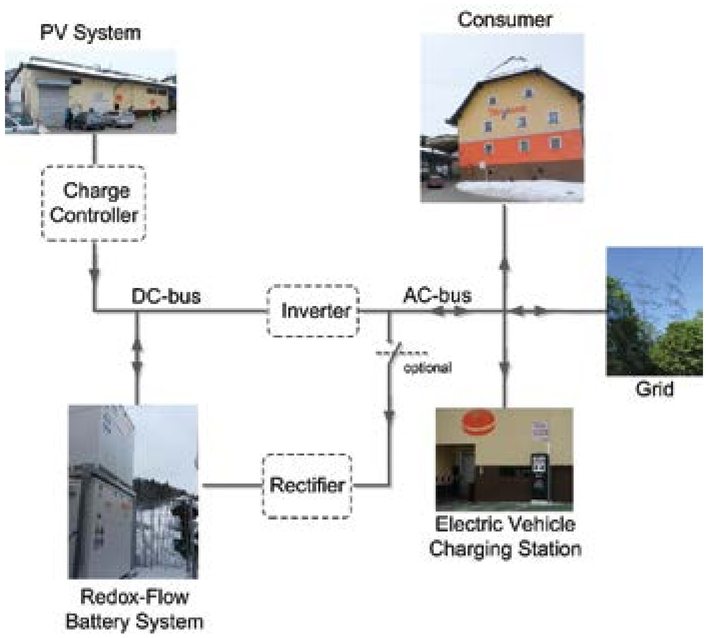

Figure 4 - Schematic overview of the installation

The installed storage units allow the restaurant to store the surplus energy from a PV source during the sunny days and use this energy on a cloudy days. It also enables peak shaving and power on failure functionalities, charging of electric vehicles from solar power plant (vehicles are charged at night when not in use) and transfer of nocturnal energy in use during the day - cheaper energy during the day. It provides power support to the EV charging station that enables lower ratings of main fusses and thus electricity costs savings. There is also a wide range of other functionalities that will be tested in future with the development of the project.

2.2 Storage technologies and frame conditions

It is today generally accepted that the high share of RES in final electricity consumption is only possible with the use of economical energy storage technologies. In addition to promoting the integration of RES, energy storage also provides:

- improved efficiency and profitability of production capacities;
- postponed costly upgrades of the transmission and distribution networks;
- avoiding unnecessary investments in production capacity needed for peak loads;
- balancing of peak loads (see figure below);
- added flexibility in the supply;
- frequency control;
- voltage support;
- increased transmission capacity;
- improved reliability and quality of power supply.

Vanadium redox flow batteries (VRB)

Different than in conventional batteries in flow cells energy is stored in the electrolyte in potentially separable liquid tanks. In that sense they are similar to fuel cells. The energy is stored in the electrolyte and discharge losses are minimal. With their near unlimited longevity they outclass most conventional batteries.

It is a technology that has been developed to practical use in the early 90s. Electric charge is stored in two components of the electrolyte ions, which are stored in their own tanks. For loading or unloading is by pumping through the converter cells, where they are separated by a proton exchange membrane. From here the name of flow batteries. Through the component of the electrolyte is lowered by using the electrode current, and thus through the membrane passing the particles and, consequently, also the charge. Larger installations of this technology (pilot implementation) of interest to the EPS emerged only in late 90s and achieve power from 1 to 15 MW and up to 120 MWh of energy.

The advantage of the technology is that it can easily reach the extent of the power and energy of interest for applications in power systems, and that does not depend on natural resources such as other technologies that meet these parameters. So it does not require interventions in space and can be used in existing facilities. It also allows for a very wide range of capacities and independent sizing of power and stored energy. The disadvantage is again higher price compared to other technologies that achieve similar or greater capacity (PSP, compressed air).

Figure 5 - A 5 kW VRB unit

2.3 Research design and schedule

The activities on the pilot project can be summarized as follows.

- Define the PV-REDOX concept;
- Define technical requirements and budget;

- Install REDOX Flow Batteries of app. 10 kW;
- Development of operation scenarios and control algorithms;
- Computer simulations of system operation;
- Implementation of the control system;
- Operation of the system and results monitoring.

Main objectives of the pilot action are as follows:

- Test the technology;
- Demonstrate transfer of daily energy into use during the night;
- Demonstrate PV system with REDOX flow batteries to enable off-grid operation;
- Demonstrate load balancing and voltage profile support with PV-REDOX system;
- Demonstrate how to increase the penetration levels of RES into the distribution networks by using energy storage systems;
- Define and quantify performance requirements, operating practices and cost/benefits levels associated with the PV-REDOX;
- Display the benefits of using RES-battery systems to general public and future users;
- Promotion of renewable energy sources;

The following key milestones and schedule were developed by the **AlpStore** project partners and Slovenian consortium:

- End of September, 2013 – Coordinating pilot activities and transnational cross-consulting;
- End of March, 2014 – Setting up and managing regional support structures;
- End of July, 2014 – Executing simulations;
- End of 2014 and beginning of 2015 – Implementing field tests;
- Feb to March 2015 – Final report of the pilot tests for decision makers (Case Study).

3 Main outcomes and benefits

Electricity storage technologies are part of the Smart Grid concept. Since these technologies are at different stages of development, one of the goals of the pilot action was to show possibilities of employing VRB storage technology that is available on the marker to provide ancillary services in distribution networks. Some of the functionalities that can be realized using VRB technology are:

- Island operation (IO) capabilities,
- Peak power shaving functionality;
- Estimation of savings in the construction (development) of the electricity network (reinforcements), if storage units are added to the large consumers;
- Transfer of nocturnal energy in use during the day;
- The balancing of schedules;
- Voltage support.

Except voltage support, other functionalities do not require high dynamic operation of the equipment. Thus, voltage support functionalities of the VRB technology together with the PV system was evaluated also by means of numerical simulations.

About Simulations

The integration of storage units in distribution networks radically affect the operation of the network and can quickly become a complex problem that cannot be effectively tackled only with the general or simplified criteria for inclusion. Approach to the problem by using simulation tools allows an assessment of the situation from different perspectives (voltage conditions, short-circuit conditions, power quality ...) and development of various measures in case of problems. Only by complete addressing of the topic, it is possible to achieve continuity of power supply and a high level of power quality.

Energy storage technologies are at different stages of development, but there is a considerable interest by the researchers and practitioners in this area. In the extensive literature and available practice covering this topic, different applications of storage technologies are presented, most of them giving very promising results.

However, not all of this applies to the control of storage devices. Namely, very little attention is paid to the problem of control, taking into account parameters of the network. This issue is particularly problematic because in the last decade, a great increase in the number of DG units have been witnessed, which brings new technical challenges to the development of distribution systems. Maintaining the voltage within the required limits is one of the most frequently occurring problems in networks with a high proportion of DG. Since DG is usually based on unpredictable renewable sources, whose production is often dependent on natural conditions (sun, wind), this can lead to voltage problems. This is especially problematic with increased production accompanied by lack of consumption.

With simulations, we focused on solving the problem regarding voltage regulation in low voltage networks by proper control of storage devices. Below simulation results will be shown.

3.1 Technical Findings

Simulation results – Voltage profile in low voltage distribution networks

Fig. 6 shows an example of a distribution feeder and its voltage profile. Nowadays voltage regulation in distribution networks is carried out mainly by automatic tap changers at the HV/MV transformers. The MV/LV transformers are usually without automatic tap changers, however, depending on the voltage conditions in the network, transformer’s tap changer can be adjusted manually under the off-load conditions. The tap changer should be set so that the voltage along the entire length of the distribution line is within the prescribed limits (+6 / –10 % for the low voltage in Slovenia).

Fig. 6-b shows voltage profile along the feeder for an example without DG (dotted line). As it can be seen, the voltage is raised at both transformers to ensure the appropriate voltage level. Thus, it can happen that the voltage at the end of the feeder exceeds the maximum allowed value (full line).

In principle, this can be prevented by lowering the voltage of the HV/MV transformer and thus bring the voltage at the end of the feeder below the upper limit. However, one should be aware that there are usually several feeders connected to the HV/MV and MV/LV transformers. If there are no DG units connected to these feeders, it is very likely that their voltage will be unacceptably low if the voltage at the HV/MV transformer is lowered.

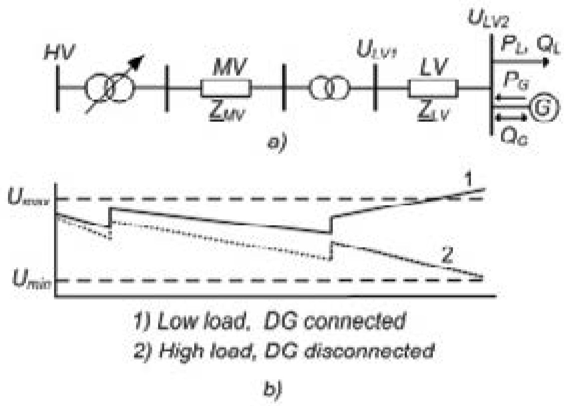

Figure 6 - Simple model of a distribution network, b) voltage profile

To illustrate some practical implications of the voltage regulation control scheme in distribution networks that was presented in details in **AlpStore**: Study for Academia Report (which can be found on the **AlpStore** web page), below a simulation case results are shown. Simulations were carried out in the PSCAD software.

The simulated distribution network with integrated PV and VRB system is shown in Fig. 7. The network consists of a power transformer TR 1 (S_{TR1} = 630 kVA, uSC = 4 %), a PV-VRB system and two radial distribution lines (r = 0.86 Ω/km, x = 0.81 Ω/km, l_1 = 100 m, l_2 = 200 m), modelled with impedances Z_1 and Z_2. The power consumption at the end of each line is illustrated by the impedances Z_{L1} and Z_{L2} (R_{L1} = 1.44 Ω, L_{L1} = 0.0015 H, R_{L2} = 2.88 Ω, L_{L2} = 0.0031 H). The remaining distribution network was simulated as a stiff voltage source with a short-circuit impedance connected in series ($S_{SC''}$ = 190 MVA). Droop characteristic data were as follows: the initial reactive power set point Q_{init} = 0 p.u. (U_{init} = 1 p.u.), the capacitive droop s_C = 0.1 and the inductive droop s_L = 0.06.

Simulation results are shown in Tab. 3. The results are given as per-unit values of voltages at bus 1 and bus 2 for four different cases: without DG (case 1), no voltage regulation (case 2), with voltage regulation (case 3) and voltage regulation by limiting the production of active power (case 4). Due to the low voltage at bus 2, the voltage at the supply transformer is raised to 1.04 p.u. From the table it can be seen that the voltage at bus 1 exceeds the maximum allowed value of 1.06 p.u. in the case without voltage regulation (case 2). In case 3, the voltage is lowered using advanced reactive power voltage control.

Reactive power consumption of 0.38 p.u. effectively reduces the voltage to 1.03 p.u. – well below the maximum limit. The same result can also be achieved by active power curtailment. The active power generation has to be limited to 0.22 p.u. (i.e. 31 % of the rated power).

Table 3 - Simulation results – voltages at buses 1 and 2, and power injection for four cases in per-unit

	Case 1	Case 2	Case 3	Case 4
Bus 1 voltage	1.00	1.07	1.03	1.03
Bus 2 voltage	0.91	0.91	0.90	0.91
P	0	0.70	0.70	0.22
Q	0	0	-0.38	0
Note: 0.4 kV, 50 Hz, 150 kVA, base.				

Field tests results

The main anticipated deliverables of the pilot project can be summarized as follows:

- Demonstrate PV system with REDOX flow batteries to enable off-grid operation;
- Demonstrate load balancing and voltage profile support with PV-REDOX system;
- Demonstrate how to increase the penetration levels of RES into the distribution networks by using energy storage systems;
- Define and quantify performance requirements, operating practices and cost/benefits levels associated with the PV-REDOX;
- Display the benefits of using RES-battery systems to general public and future users;
- Promotion of renewable energy sources.

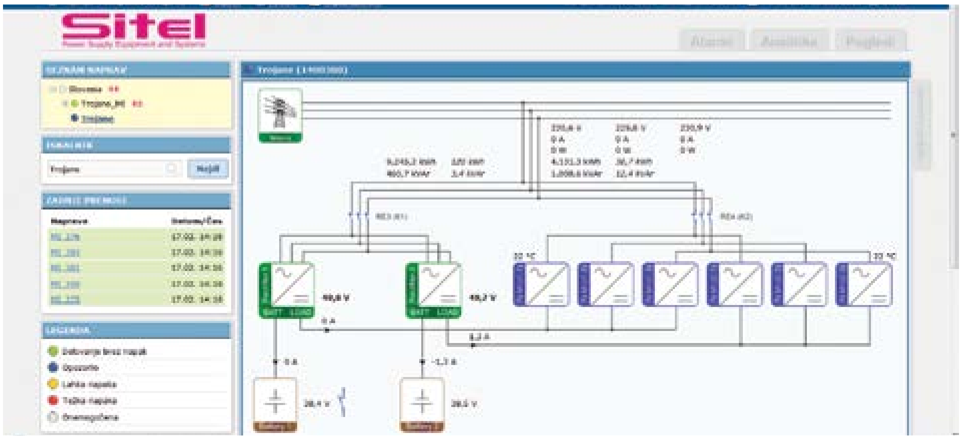

Figure 7 - Sitel application developed to control the system

Figure 8 - Sitel application showing charging/discharging of the VRB units

3.2 Social benefits

The Trojane restaurant was considering to integrate renewable energy sources and advanced storage units in their electricity supply for some time. Excellent sunny location and large electricity consumption were for them main driving factors to go in this direction that finally brought them double satisfaction. First, they reduced the cost of energy consumption, secondly, as a company to acquire green energy, which is environmentally friendly and which is something that they can show to their guests.

With regards to the general trends, they set a goal to make as many product as they can from organic ingredients and to thermally treat them with environmentally friendly energy. They believe in setting high standards for the preservation of the natural environment and to show good example to their guests.

4 Conclusions

This document presented Slovenian pilot action that was implemented in a small village Trojane. In the first part of the document, it highlighted challenges and constraints on the one side and opportunities and benefits of the existing storage technologies for regional energy system on the other side. The **AlpStore** project and the STORM concept were also presented. In the second part of the document, redox flow batteries and pilot implementation process were presented. Finally, simulation and field test results were shown.

We can conclude that the PV-VRB DG system with the presented control scheme is capable of effectively compensating the voltage rise, while maintaining constant active power injection from the PV source. The pilot action also demonstrated how to increase the penetration levels of RES into the distribution networks by using energy storage systems, it defined and quantified performance requirements, operating practices and cost/benefits levels associated with the PV-REDOX system and it showed the benefits of using RES-battery systems to general public and future users.

4.1 Follow-up plans

Many of the energy storage systems include new technologies that are still very expensive and thus operation of storage systems is not economical. A huge development in this area is expected in the next years, and in order to be prepared, the installation of pilot projects should start as soon as possible.

The Slovenian **AlpStore** consortium will of course take an active role in this process. With the PV_REDOX pilot installation we will be able to educate students and young professionals on the practical issues related to the installation and operation of battery system, which will be crucial in future years. The pilot project will also serve as an example for other similar installations that will definitely be needed in certain remote areas of the Alpine space.

4.2 Transferability to other Alpine regions

Gained experiences within the pilot implementation will in future allow us to develop cross-border energy concepts for the use of RES, establish cross-border cooperation between companies in the field of RES and energy storage and breakthrough in the use of efficient and environment friendly energy in the range of the Slovenian-Austrian state border.

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Oberallgäu, Germany
PV-Store^{plus} E-Bike
Case study

Project Partner: B.A.U.M. Consult GmbH

Authors: Ludwig Karg, Christopher Jahn (B.A.U.M. Consult), Felix Geyer (eza!)

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Case studies are contributing to AlpStore WP6

Work Package 6 Responsible: EUROIMPRESA LEGNANO s.c.a.r.l.

Lead Partner: B.A.U.M. Consult, Ludwig Karg, Patrick Ansbacher, Anja Lehmann

1 Storage technologies for the region Allgäu - general frame conditions and objectives

Based on the ambitious goal of reaching a share of 70% of electricity consumption coming from renewable energy sources in the region, the storage master plan identified important potentials concerning storage for the entire Allgäu region. It includes a list of advantages and disadvantages of small-scale storages for households, the elaboration of decentralized energy storages in local network stations in a pilot project (IRENE), and the establishment of smart grid projects. The master plan also values the need for social acceptance and participation of local citizens, and includes public relation measures to reach this goal. Finally, the master plan includes steps to connect different activities in the future and names first concrete projects.

For further information and the Master Plans of all regions, please visit the **AlpStore** Website (http://www.alpstore.info/).

1.1 Actual regional energy system

Energy Production

Table 1 shows an overview of all installed power plants in the area Oberallgäu/Kempten in the year 2012 including number of plants, produced energy in the year 2012 and percentage of energy production in comparison to the total consumption in the investigation area. Most of the time the Oberallgäu region imports energy; there is no conventional base load power plant in the area. Hydropower plants provide the regional produced base load. In the entire investigation area, there is one conventional power station, a peak load power plant (gas turbine, combined with a diesel generator) in Sulzberg-Au. However, there are plenty of distributed photovoltaic installations with an installed capacity of about 150 MW.

	installed capacity [kW]	number	produced energy [kWh]	percentage in total consumption [%]
water	44,302	104	167,082,253	**14.2%**
wind	18,905	12	21,779,364	**1.8%**
photovoltaic	137,107	7.325	128,636,281	**10.9%**
biomass	10,612	54	50,434,045	**4.3%**
sewage gas	374	1	18,002,731	**1.5%**
natural gas	3,824	127	8,381,164	**0.7%**

Table 1 - Overview - installed power plants in the investigation area Oberallgäu/Kempten 2012 [source: AÜW GmbH]

Energy Consumption

In 2011, the households, enterprises and traffic in the pilot region Oberallgäu consumed 6,574,918.5 MWh of end energy. That includes heat – from fossil fuels, renewable energies and bio-mass – and electric energy. The consumer group 'economy' consumed 44 % of the end energy followed by the sector traffic with 31 %. 25 % of the end energy demand account of the sector 'households'.

The final energy consumption of business clients is dominated by oil and natural gas. Firewood plays a minor role. The overall consumption of business clients in 2011 was 1.99 TWh. In private households, heat is mainly generated by oil and natural gas and firewood. The share of natural gas increased over the last years.

Energy Transmission and Distribution

There are seven distribution grid operators in the area of the **AlpStore** pilot region Oberallgäu/ Kempten. Five of them form the Allgäu Netz GmbH & Co. KG (short: AllgäuNetz). The supply with electrical energy in the grid of the AllgäuNetz happens via the voltage level of the high voltage 110 kV, the middle voltage 20 kV and the low voltage 0.4 kV. For the supply in urban areas as also in rural areas, the middle voltage level of 20 kV is used.

The 110 kV high voltage grid of the AllgäuNetz is connected with the high voltage transmission grid of the Lechwerke AG (LEW) and is fed out of the 220/110 kV substations of Kempten Au and Rauhenzell. The part of external procurement compared to the complete current delivery has been around 79.1 % in the year 2008. The part of the remaining 20.9 % has been feed in during this period with renewable energies as well as with thermal power stations.

Table 2 provides an overview of the number of metering points of the Allgäu Netz.

voltage	high	high/medium	medium	medium/low	low
number	18	60	2,210	3,160	137,035

Table 2: Metering Points Allgäu Netz GmbH & Co. KG, source: Netz- und Strukurdaten der AllgäuNetz GmbH & Co. KG 2012

In 2009, a new concept has been developed to supply the 110 kV grid by the existing 380 kV transmission network. According to this concept, a change of the feed-in from the 220 kV level to the 380 kV level is planned for the near future. The backup supply will continue to be supplied by the 110 kV level. As the first step in the year 2015 it is planned to replace the 220/110 kV transformer in substation Kempten Au with a new construction of the 380/110 kV substation Leupolz. The complete supply of the 380 kV grid will be probably given in the year 2020.

Energy Storage

Pump storage: As a result of a feasibility study of the AÜW, a capacity of 60 - 100 MW in Rettenberg near the existing lake “Rottachspeicher” seems to be possible. The two pump storages could provide power for 4 - 6 hours; this totals to an amount of 240 - 600 MWh for one cycle. The plan is to start the realization in 2018 and commissioning is scheduled for 2020/2021.

Thermal energy storage-systems – Low temperature: In Kempten, the operator of the waste incineration plant – the Waste Management Association (ZAK) – is installing heat storage in addition to the district heat. There will be two storage tanks with 240 cubic meters each. In the volume of 480 m³, the amount of 33 MWh can be stored and used for balancing the district heating network. The energy stored in the buffers provides thermal energy for 3-4 hours.

Power to heat: The Waste Management Association (ZAK) is investigating the possibilities to provide a secondary reserve with the waste incineration plant in Kempten Ursulasried. The plant provides heat for a district heating system in Kempten. It will be equipped with a thermal storage (2 x 240 m³). In this system, a continuous-flow water heater with a load of 5 MW can provide control energy. The capacity of the waste incineration plant – combined heat and power generation – is 30 MW.

Mobile batteries (electric vehicles): There are some projects in Allgäu region dealing with electric mobility. Since the project "eE-Tour Allgäu" (2009-2011) there is a charging infrastructure available with app. 14 public charging stations. eE-Tour Allgäu also brought the first electric vehicles to the region. Meanwhile nearly 60 electric cars are registered in the Allgäu region (status 31.12.2012). Further projects in this area are "IRENE" (results are being evaluated) and "econnect Germany".

Stationary batteries: In Wildpoldsried, a stationary battery system was installed by the end of September 2012 in the frame of the project "IRENE". It is a lithium battery with a capacity of 138 kwh with 300 kW power. The dimensioning was optimized to the power and the load of the grid in this village.

1.2 Future regional energy system

Energy Production

There are no plans to build new conventional plants in the pilot region. In the future, the Energy production will be based mainly on renewable energies.

Water: The existing hydropower plants produced 167,082 MWh in the year 2012. A potential for new facilities exists only in a few cases because of current legal framework and water management regulations. By optimization/repowering of existing hydropower plants, the yields of small facilities (<50 kW) can be improved by approximately 25 %. For facilities with a capacity of over 50 kW, the improvement can be approximately around 10 %. The potential for energy production of electric energy in the district is 2,357 MWh per year. The small hydropower plants produce a share of 58 MWh per year.

Wind: For the realization of further wind energy plants, currently many "hurdles" exist that need to be overcome. Different aspects have to be considered. In order to achieve the 2022 vision of the region however, the construction of 40 more wind turbines is necessary. Elsewise this goal is unavailable. Taking into account the possible technical potential in the district Oberallgäu is 850,808 MWh per year. Against this background, the remaining potential is 821 GWh per year for the pilot region.

Photovoltaic: By reference to the so-called "Solarkataster" from AÜW, the yield is calculated with a specific output of 90 kWh per m^2. For 1 kW$_{peak}$ an area of 10 m² is assumed. This is a rather conservative approach but the growing trend is to use east/west-orientated or low inclined roofs for the production of energy. The surface roof, which is usable for photovoltaic systems, is 6,985,932 m^2. In the year 2011, from this 1,012,192 m² were already used and 5,973,741 m² were remaining. With an average output of 90 kWh/m²*a, this is a potential of 537,637 MWh per year. Including the potentials of open space systems of 49,788 MWh/a, the total potential for the production of electric energy is 587,425 MWh/a.

Combined heat and power generation: An annual electric energy production of 118,428 MWh is potentially possible (based on the EEG 2012). In the Allgäu, 185 biogas plants already exist. 78 are in the district Unterallgäu, 76 in the district Ostallgäu and only 31 in the districts Oberallgäu and Lindau. They produce the amount of 274,000 MWh. The theoretical heat potential is estimated with 200,000 MWh.

Energy Consumption

Savings in consumption and increase of energy efficiency through the introduction of energy management systems according to DIN 16247 and/or DIN EN ISO 50001 (business clients >100,000 kwh/a). Small-scale businesses (<100,000 kwh/a) offer potential for load shifting as the project AlpEnergy also examined. This potential should be further investigated and business models for this are analysed.

The specific load profile is going to change in future due to the possibility of self-consumption of energy from PV-systems. Through the decrease of the feed-in tariffs, self-consumption is more and more attractive for the consumers. If grid-parity is achieved, the costs for self-generated energy is lower than the costs for energy from the utility company.

Energy Transmission and Distribution

In the Allgäu Netz service area, the maximum annual load in 2011 was 238 MW. The capacity of the already installed PV-systems was 109 MW in 2011 (in May 2013 the installed capacity already increased to 138 MW). Since the introduction of the EEG in Germany in 2000, the installed capacity of RE in the AllgäuNetz area has increased constantly. Especially in recent years, the installed capacity of 20 MW of PV in 2006 has increased to almost the sevenfold, namely 140MW in June 2013. The result of this progress is that the number of back feeding events from the AllgäuNetz low voltage grid into the European grid increases constantly every year (50 times in 2012). The period and the capacity also increase tremendously.

Energy Storage

Biogas digesters and storage tanks: The actual energy production from biogas plants is 80,086 MWh/a. The technical potential is about 309,814 MWh/a. This means a possible increase of 287 %.

Compressed air storage: Geologically considered, the underground in the region Oberallgäu is flysch and molasses; there are caverns or caves that can be used for storage. Occasional salt domes are possible but not considerably deducible. If they were, the stone is too porous for a usage as storage for compressed air.

Pump storage: There is a detailed investigation of 20 locations in the Allgäu; two of these are concrete of interest: Breitenstein and Rottachspeicher: every location could have 40-60 MW, about 360 MWh of electricity per sequence; realization possible within 8 - 10 years.

Stationary batteries: Within the investigation area, there is a potential of 15,000 private households with a usable roof area for PV-plants connected with stationary batteries. That would produce a storage potential of 135 MWh/a central-decentralised storages (capacity per battery 8 - 10 kWh).

Central-decentralized storages: About 80 % of the PV-systems are installed in the low voltage grid. In order not to limit the additional installation of photovoltaic systems, the low voltage network has to be expanded. As alternative to the expansion of the grid, local network storages could help to stabilize the voltage in the grid and prove reactive power. It is still not clear if this is a market model for the distribution grid operator or the energy supplier. The “Unbundling” in Germany makes it difficult to develop business models with battery storages. A new role of the memory market operator could be the result of it.

Small storage-cluster: The aim of the users of small battery storages is the avoidance of purchasing electricity from the power supplier. Their general interest is in saving costs. In order to be useful for the stability of the power grid, the storages have to be combined to a virtual system.

1.3 Regulatory framework

Regional Framework – Oberallgäu/Kempten

In the region of Oberallgäu/Kempten the "Regional Planning Association" decides on the regional plan and its amendments and discusses the interests of its members within the framework of regional planning. Beside "Oberallgäu" and "Kempten" the region 16 contains: Lindau, Ostallgäu, Kaufbeuren. After the events in Fukushima and the following decision of nuclear phase-out until 2022, a perpetuation of chapter B IV 3.2 (utilization of wind power) in "Regionalplan der Region Allgäu" (regional plan for region Allgäu) has been decided at the meeting of the planning committee of the Regional Planning Association Allgäu on 10 June 2013. The aim of the perpetuation is to check the regional area once again in detail. Based on today's valid criteria an evaluation shall reveal, if and where there are possibilities to build wind power plants in the region Allgäu. The main target thereby is to implement the energy transition and, in particular, to shape the utilization of wind power substantially on its own and as suitable for the region as possible.

The goals of Bavarian Energy Policy

Bavaria's goal is to generate 50 % of its power consumption from renewable energy sources by 2021. Hydroelectricity is to contribute 17 %, solar power 16 %, bioenergy 10 % and wind energy 6 to 10% of the total power consumed. From now until 2020, CO_2 emissions are to be reduced down to considerably less than six tons per capita, while keeping electricity prices affordable for all consumers and maintaining current security-of-supply levels.

2 Pilot project PV-Store^plus E-Bike

Bicycles with engine support have a rising tendency for years. Not only the private usage of so called e-bikes[1] is growing, but there is also a rising tendency for e-bike tourism in Germany. It offers a combination of physical exercise, nature experience and touring. Especially, nature tourism is in great demand. That is mainly due to the rising awareness for the environment. This leads to more people deliberately choosing sustainable tourism.

At pilot locations in an alpine hut near Oberstdorf and an old farm near Sonthofen, the PV-Store^Plus E-Bike was installed as shown in the picture below. The goal was to build a self-sufficient energy system, which is able to store electricity generated with solar modules in an energy storage built from second use batteries, i.e. batteries that due to reduction in the capacity cannot serve as traction batteries for e-bikes anymore. Batteries used in e-bikes rented from MOVELO (model "Flyer") can be charged in the energy storage rack right away, other batteries can be charged via their respective connectors.

[1] Mostly this term refers to so called pedelecs which support the physical power of their rider rather than replacing it.

source: **AlpStore** Consortium, 2013

Fig. 1 Simplification of the PV-Store^Plus E-Bike set up

Involved AlpStore partners

B.A.U.M. Consult - With offices in Munich, Berlin, Hamburg, Stuttgart and Hamm B.A.U.M. Consult GmbH supports enterprises, municipalities, regions and governmental institutions throughout Germany and abroad with consultancy and training on sustainable development. As a knowledge management company, B.A.U.M. understands its role as a link between development, production and marketing of sustainable products and services.

B.A.U.M. supports enterprises to develop sustainable and environment friendly products and to win market shares for their offerings with marketing campaigns, helps enterprises and municipalities to establish environmental and sustainability management like ISO 14001 or EMAS in their respective organizations. Through its Regional Development Department, B.A.U.M. helps to build regional market and branding systems with emphasis on local food and energy provision.

B.A.U.M. manages research and development programs and organizes conferences and experience exchange events on behalf of governmental and entrepreneurial organizations. The B.A.U.M. International Department is partner in various EC projects. It helps other companies and local governments in the application process for EC and worldwide funding and with coordinating huge projects. In international projects, scientific studies and regional development B.A.U.M. today concentrates on fostering usage of local renewable energy sources and sustainable mobility patterns.

Energie- & Umweltzentrum Allgäu (eza!) is a non-profit corporation that was founded by the municipalities of the Allgäu, by businesses and action groups to promote both energy efficiency and renewable energies. The motto of eza! is “answers to energy questions”.

eza! offers a wide range of services. They include media work and organisation of events, energy consultations, training schemes for professionals and support for local and regional energy policies. eza!’s core service is the field of energy consultations. In cooperation with the municipalities, forty local offices and their unbiased experts provide information free of charge for the inhabitants of the

Allgäu region. More than 130 businesses in the building and energy industries, including architects, building contractors and craftsmen, belong to the eza!-partner Network.

eza! is well known as an further education institution for energy and building professionals. eza! is deeply involved in the elaboration of local and municipal energy and climate protection plans for many municipalities and regional local authorities (Landkreise) in the Allgäu region. In addition eza! is regional office and consultant for the European Energy Award®. Another service for municipalities and business (SMEs) is energy consulting and energy management.

AlpStore partner **AÜW (Allgäuer Überlandwerk GmbH)** since more than 90 years provides energy and related services to the city of Kempten and other customers in the Allgäu, a famous tourist area located in South-West Germany. As the biggest regional supplier of electric energy, the Allgäuer Überlandwerk committed itself to the task "energy for the Allgäu". Together with partners such as AKW, EVO and others, there is a close cooperation under the name of „AllgäuStrom". The AllgäuStrom cooperation serves over 125.000 customers. The competence, know-how and commitment of AÜW – not at last gained from Alpine Space funded projects - are transferred to municipalities and cities of the region.

The Allgäu is blessed with solar radiation in abundance and is therefore equipped for further construction of renewable energy plants. The use of hydro-electric power has a long tradition in the region. AÜW owns 8 hydropower plants; the biggest has a power of about 5 MW. This shows the enormous dedication to increase the part of renewable energies in power generation. In the year 2010 already more than 25 % of the complete consumption has been produced by endogenous renewable energies. The aim of AÜW for 2020 is to reach an amount of at least 40% or more produced by renewable energies in the region.

Regional Stakeholders

Oberstdorf is a municipality in the very south of Germany and is surrounded by the Allgäu Alps. For this project, the **Oberstdorf Tourism organization** has been selected as an implementation partner, providing co-funding and support in various aspects.

Sonthofen, located between the rivers Iller and Ostrach and surrounded by the panorama of the Allgäu Alps, is the southernmost city in Germany. It borders almost immediately to the neighbouring countries of Switzerland and Austria. With 4,000 beds, in categories ranging from basic holiday flats to first class hotels, Sonthofen is one of the most important touristic towns in the Allgäu.

Movelo is Europe's largest provider of electric mobility in tourism and cooperates with the Swiss company Biketec AG. Until now, the unprecedented collaboration of an electric bicycle manufacturer and a tourist service companies made them pioneers of innovative concepts and systems for electric mobility.

WEMAG group of companies includes subsidiaries WEMAG Netz GmbH, e.dat GmbH, WEMACOM GmbH and the mea GmbH. In addition, WEMAG is involved in various other companies. The ReeVolt energy storage – developed by WEMAG AG in cooperation with MOVELO and based on recycled e-bike batteries – has been used for the **AlpStore** project.

2.1 Characteristics of the field test

The idea

Basically, the PV-Store^{plus} E-Bike had two different goals. The first goal was to build a self-sufficient energy system, which is able to store electricity generated with solar modules in an energy storage. In addition, the storage should build on second life batteries. The second goal was to establish a new charging and exchange station for e-Bike tourism. In order to match these two goals, a concurrent use had to be considered. Another important aspect concerning the storage technology was that the batteries used in e-bikes rented from MOVELO (an e-bike rental provider) could be charged in the energy storage right away or via an external charging device. Based on these overarching goals, the implementation sites and the storage technology had been selected.

Choosing the implementation site

The **AlpStore** pilot Implementation PV-Store[plus] E-Bike is located in the upper Allgäu Region, Bavaria, Germany. Two different test site partners have been chosen, the municipality of **Oberstdorf** and the city of **Sonthofen**. MOVELO, the e-bike rental provider, supported the test as well.

source: B.A.U.M. Consult, 2014

Fig. 2 Buchrainer Alpe near Oberstdorf

Implementation site 1 – Buchrainer Alpe (see Fig. 2):

The first criterion for choosing the right implementation site was the distance of the planned facility to already existing e-bike charging stations.

The second criterion was the proximity to highly frequented cycle tracks. Travellers will decide on their own individual ability - but also on the technical capability of their e-bikes, how much further up the hills they are willing to go.

A further criterion was the discharging of the e-bike batteries. Independently from the individual journey starting point, it is assumed that after travelling steep uphill sections on the way from Oberstdorf into the Rappental, most e-bike batteries will already be discharged to a significant amount. In average reaching the Buchrainer Alpe batteries will have lost 50-70 % of their power. At this point, a nearby break to switch or recharge batteries and / or enjoy a rest seems suitable.

The central argument, regardless of the suitability was the feasibility for the implementation. Taking into account all arguments, the Buchrainer Alpe has been chosen as the pilot implementation side. A welcome confirmation for choosing the Buchrainer Alpe for the implementation is the fact that years ago MOVELO had selected this point to suit very well as a battery exchange station and contacted the hut operator a while ago for negotiations about being part of their e-bike network.

source: Stadt Sonthofen, 2013
Fig. 3 Biberhof in Sonthofen

Implementation site 2 – Biberhof (see Fig. 3):

The second implementation site is located outside the city of Sonthofen. Three locations had been under discussion. One was located more in the city centre close to the city hall; one would have been connected to an arena for sport events called Blank Arena. The third location is called Biberhof Sonthofen, an old farm now being used for learning and demonstration purposes in the field of sustainability.

Due to the following criteria, the third option – Biberhof Sonthofen – has been chosen:

- high technical plausibility: stand-alone power system because of lacking grid connection
- solar array can be adjusted to the demand of energy storage and to the demonstration within the project
- small facility with 1-1.5 kW_{peak}, presumably payable through climate funds of local grid operators
- no structural or statical problems: lightweight construction, minimum additional load (approx. 20 kg/m²)
- low investment costs
- can be quickly realized
- leisure structures available in close proximity: Blank-Arena, Wonnemar, sports stadium
- nearby bicycle and hiking trail alongside river Iller
- capable of being integrated into the Biberhof´s concepts for demonstration and education: part of the Montessori education, guidance to an integrated, sustainable object, over time customizable demonstration object for internal energy consumption and stand-alone power solutions.

Selection of storage system

As mentioned before, the selection of a battery system that fulfils the requirements was the key to reach the objectives. The result of the research process was, that there are only few projects working with 2nd life batteries and only the company WEMAG is about to launch its ReeVolt system and has their product certified by the standards (IEC 60950-1:2006, EN 61000-6-3:2007+A1:2011).

Research question	Activity	Responsibility	Schedule
What solutions are available using 2nd live batteries?	desktop research, consultations with experts	B.A.U.M. / FFE	1-3 Month / finalized in February
Are there solutions to be expected in the near future? At what development stage are they?	research on projects working on batteries and recycling processes consultations with experts	FFE	1-3 Month / finalized in February
What are the must have characteristics of the systems to be flexible enough for the scientific requirements?	developing a study design	B.A.U.M.	
Are the identified solutions certified under standards, which allow the operation on public and private ground?	analysis of product sheets consultations with producers	FFE	1-3 Month / finalized in February

Table 3 - Criteria for selection of the battery system

According to these exclusion criteria, the ReeVolt system seemed to be the only choice for a system which is flexible enough to implement all research activities. Furthermore, the modular design of the ReeVolt system is an important fact. Before the implementation process, the detailed requirements of a storage system for the Buchrainer Alpe were not clear, e.g. storage period or storage capacity. This should be all part of the investigation in the implementation process. Therefore, the ReeVolt storage system satisfied this need by its modular design. The storage capacity can be changed arbitrarily. Depending on how many batteries are locked, the capacity increases or decreases.

Finally, at the end of the selection phase, a contract with WEMAG to participate as an active partner in the project was closed. Two boxes were ordered for Buchrainer Alpe and Biberhof on a rental base for six months.

2.2 Frame conditions and storage technologies

E-bike boom

Since 2008, the e-bike market is evolving. In 2012, 380,000 electric bicycles have been sold in Germany alone. That is an annual change of 15 %. The uptrend is not only due to the ever-evolving battery and due to engine technology (Zweirad-Industrie-Verband 2013). The higher gas prices and an increasing sensitivity for the climate and environment contribute to the boom of the e-bikes (Grett et al. 2011).

The Zweirad-Industrie-Verband e.V. (ZIV) estimates an annual disposal of 600,000 e-bikes in Germany (Kolberg 2012). Regarding the increasing demand, the number of producers is rising as well. Nearly every bicycle producer has e-bikes in its range and the automobile manufacturer follow-up with their own products (Tamoschat 2012).

The German federal government proclaims to target 1 million electric vehicles in transit on German streets (Zweirad-Industrie-Verband 2013). This was already outreached by e-bikes alone without any government aid. In the beginning of 2013, 1.3 million electric bicycles were in use in German traffic (Zweirad-Industrie-Verband 2013).

Sustainable tourism in the alpine region

Tourism in the Allgäu has been on an upward trend for years. Variety and quality are the benefits of the region (Zehnpfennig 2013). Bicycle touring and especially the e-bike tourism are affected by the rising trend (Grett et al. 2011). Touring with an e-bike is also known as soft tourism (Elektrofahrrad 2013).

However, touring with an e-bike is only sustainable when the used energy derives from renewable energy sources. For this reason, the PV-Store plus e-bike project guaranteed the sustainability of the energy supply. It was very important that the project could underline the three aspects ecology, economy and social factors. The concept only applies to be sustainable if these three aspects are in line with each other (Freericks et al. 2010). Hence, also second life batteries were used.

The **ecological aspect** only fulfils itself if there is as minimal interference into the ecosystem as possible. Moreover, should changes that affect the ecosystem be avoided or minimized as much as possible (Freericks 2010). The ecologic aspect should always be the top priority for the benefit of the sensitive alpine and Allgäu ecosystem (Stankiewitz 2012). Considering this incentives, the used energy for charging was generated from 100 % solar power. Furthermore, second life batteries were used as storage (series connection) for the chosen storage system (see ReeVolt battery system).

The **economic effect** is multifaceted. The tourism boosts the economic development of the region, especially the catering, hotel and retail industry. This leads to more employment and higher living standards (Freericks et al. 2010). Through the pilot implementations two new charging and exchange stations for local e-bike tourism established. Through the sustainable concept, the regional stakeholders can benefit from the developments of a European research project.

The third aspect to be considered is the **social factor**. Social values like distributive justice are eminently vital. That applies mostly to quality of life. Therefore, locals shouldn´t suffer from drawbacks caused by tourism. In addition to that are social and cultural structures important (Freericks et al. 2010). The project supported also this area. The project revaluates the region through connecting sustainability with high technology. The replacement of the battery leads to an expanded range and more opportunities for route planning. The implementations sites are also interesting destinations for day-trippers. Especially the Buchrainer Alpe, which is a “Sennalpe” from the 17th century with a rustic charm.

ReeVolt battery system

source: B.A.U.M. Consult, 2014

Fig. 4 ReeVolt battery system in the Buchrainer Alpe

The ReeVolt System is based on reusing e-bike batteries. The technical data of the batteries (when new) are:

- Producer: Panasonic
- Type of battery: Lithium ion
- Work: 260 Wh
- Voltage: 26 V
- Capacity: 10 Ah
- Number of cells: 16 cells

The used batteries are provided by e-bike manufacturer SWISS-FLYER. After two years of usage in the renting program, the producer cannot give a 100 % guarantee for their performance and therefore the rental provider returns them. The remaining capacity averages around 80 %. The returned lithium manganese batteries are available in great amount, which makes this concept sustainable in comparison to other storage systems (WEMAG 2013). Further parameters of the ReeVolt battery system are shown in Table 4.

2.3 Research design and schedule

Operation and monitoring

As mentioned in chapter 2.1, the idea was to build a self-sufficient energy system, which is able to store electricity generated from solar modules in an energy storage equipped with second use batteries. In addition, the storage should be able to swap and charge exchange batteries from MOVELO right away or via an external charging device.

To analyse the functionality and acceptance of the ReeVolt storage system, the following central questions should be answered during the test phase (see Table 5).

Parameter	
Nominal power grid operation	11,500 W
Nominal power battery operation	3,000 W
Capacity	up to 5 kWh (2,5 kWh guaranteed for 16 batteries)
Dimensions	60 cm x 60 cm x 84 cm
Weight (with/without batteries)	135 kg / 95 kg
Input	230 V / 50 Hz / 50 A
Output (transfer / battery operation)	230 V / 50 Hz / 50 A / 13 A island operation
Standards system	IEC 60950-1:2006, EN 61000-6-3:2007+A1:2011
Standards inverter	EN 60335-1, EN 60335-2-29, EN 55014-1, EN 55014-2, EN 61000-3-3

Table 4 Parameters of ReeVolt system, source: WEMAG, 2013

Research question	Activity

Can a storage based on 2nd life batteries reasonably and practically enlarge an existing off-grid PV system?	Collecting data to compare the situation before and after installation. This data is:
	• Technical functioning data from the ReeVolt System about charging and supplying processes. All data is logged inside the system and can be downloaded from a local connection
	• Data about generation from the charge controller
	• Quality of use from interrogating the tenants about defined consumption processes
	  • Next to each test set, a concrete questionnaire will be filled out immediately after all test activities
	  • two times in the testing period interviews with open questions will be held for user feedback
	  • If possible, a short questionnaire will be handed out to tourists recognizing or using the PV-Store^{Plus} E-Bike
	• Expenditure on the storage as offered to customers

Can electric mobility (here especially e-bikes) be extended by the use of renewable energy technology independent from a connection to a grid?	• Interrogating users (tenant and e-bike tourists) of the system at both pilots

Question for Biberhof only: can a storage based on 2nd life batteries reasonably and practically serve as a charging spot for e-bikes, especially in remote areas with no personal assistance and without connection to the grid?	• Technical functioning data from the ReeVOLT System about charging and supplying processes. All data is logged inside the system and can be downloaded with a local connection

Table 5 Research design, B.A.U.M. Consult, eza!, 2014

For data collection, a detailed analysis report was designed. The acquired data was analysed statistically. Of course, different conditions had to be taken into account. For example, at the Buchrainer Alpe, the existing system (stirrer, water filtration) must always operate reliably.

To answer the question about acceptance "**Do guests and residents recognise the concept and what kind of opinion do they form about it?**" a detailed questionnaire was designed – answered first by the tenants of the hut in Oberstdorf.

To analyse strength and weaknesses of the new system, a calculation tool based on Excel was developed. For the calculations, the tool uses the regional solar radiation data (reference calculations). With this tool, various parameters such as capacity of the existing battery system, number of batteries, generation capacity or self-discharge of the storage can be entered or changed. This tool enabled the execution of various simulations (see chapter 2.4).

Milestones

Activity	Date
Final and consolidated Implementation Plan	31/03/14
Technical installation up and running	31/05/14
Start of operating phase	01/06/14
Successful end of operating phase	31/10/14
Case Studies with all results distributed	24/12/14
Pilot Implementation finalised	31/12/14

Table 6 Milestones, source: B.A.U.M. Consult, 2013

Schedule

	01/14	02/14	03/14	04/14	05/14	06/14	07/14	08/14	09/14	10/14	11/14	12/14
Preparing Implementation Plan	■	■	■									
Selection of Technology and Consolidation of Plan			■	■								
Technical Installation of Pilot					■	■						
Operation and Monitoring					■	■	■	■	■	■		
Communication Activities				■	■	■	■	■	■	■	■	■
Case Study Reports for Political Decision Makers and Technical Practitioners											■	■

Table 7 Schedule, source: B.A.U.M. Consult, 2013

2.4 Implementation process

Phase 1: Dimensioning the PV-Store^Plus E-Bike System

Sonthofen Biberhof

At this site a new PV module had to be installed. To design the PV-system and to find a suitable storage system, different parameters had to be taken into account:

- Static structure of the roof: the construction is very weak and the roof tiles are (due to their age) very fragile; installing the PV-system on the roof may cause problems and high costs
- the orientation of the roof is east and west; this does not have to be a disadvantage for self-consumption, the rate of self-consumption depends on the load-profile
- the south oriented facade could be used for installation of the PV-system, but there will be shadings by the eaves of the roof; limited surface area: place sufficient for approx. 6 modules (0,90m x 1,60m)
- no load profile available, the daily consumption has to be estimated.

source: eza!, 2014

Fig. 5 Schema pilot implementation Biberhof Sonthofen

Based on reference values, the monthly yield of PV-systems of different sizes (number of modules with 205 W_{peak}) was estimated. In the next step, the average daily production of the PV-system was determined. For a typical size of a Pedelec-battery, a capacity of 650 Wh was assumed. If the average daily production is divided by the capacity of the batteries, the possible number of loading operations could be calculated.

Given that the high season for the touristic use of the charging spot at the Biberhof is from March to October, a PV-system with ~1.000 W_{peak} should be the minimum.

This allows for 3 up to 8 charging operations per day. With a power capacity of ~2.000 W_{peak} the number of charging operations could be raised up to approx. 16 per day. On the other hand, it is not yet determined how frequently the charging spot will be used. The available area at the south façade was sufficient for the installation of the 6 PV-modules (205 Wp). This gives a yearly yield of ~750 kWh/a. The chosen PV-system was combined with the ReeVolt storage system. A simulation with the Pvfin-tool showed that most of the energy produced by the PV-system could be directly consumed. The battery storage can lend support to the electrical power supply for the building, especially on sunless days or in the evening. To that end, the new system could replace the diesel aggregate that had been frequently used before to provide power for the Biberhof.

Buchrainer Alpe Oberstdorf

source: B.A.U.M. Consult, 2014

Fig. 6 Schema pilot implementation Buchrainer Alpe

The challenge for this location was to integrate the ReeVolt system into an existing off-grid system. An enlargement of the solar modules was very likely to be needed, because, at the moment of the installation, a shortage of electricity was felt especially in the months September and October.

As a result of the expansion of the storage capacity, further appliances could be integrated into the electricity network of the hut.

To dimension the required size of the solar array, different methods were considered. In any case, it was necessary to use additional data to estimate the environmental factor appropriately. The following design parameters had to be taken into account.

Designation	Formula symbol	Unit
Irradiation of the global radiation	H	kWh/m²
Global radiation factor	R(β, γ)	-
Generator correction factor	k_G	-

Table 8: Design parameters

Only the tourism relevant holiday season from March until October was considered for the PV Store plus E-bike project. The data is open to the public.

	Mar	Apr	May	June	July	Aug	Sept	Oct
H in kWh/m²	3.83	5.16	5.17	5.29	5.27	4.88	4.08	2.93
R(β, γ)	1.19	1.08	1.01	0.98	1.00	1.05	1.16	1.27
k_G	0.81	0.83	0.84	0.84	0.84	0.84	0.84	0.82

Table 9: Radiation values, global radiation factor and generator correction factor, source: European Commission, 2013, Häberling, 2010

Further calculating steps can be seen in Table 10 and Table 11.

Designation	Formula symbol	Unit
Radiation yield	$Y_R = \frac{R(\beta,\gamma)\cdot H}{1 \frac{kW}{m^2}}$	$\frac{h}{d}$
Module charge	$Q_S = k_G \cdot I_{Mo} \cdot Y_R$	$\frac{Ah}{d}$
Numbers of modules	$n_{SP}' = \frac{Q_L}{Q_S}$	-
Approximated numbers of modules	n_M	-

Table 10: Design parameters for the photovoltaic battery

	Mar	Apr	May	June	July	Aug	Sept	Oct
Y_R [h/d]	4.56	5.57	5.22	5.18	5.27	5.12	4.73	3.72
Q_S [Ah/d]	29.39	36.82	34.91	34.66	35.24	34.26	31.65	24.29
n_{SP}'	2.08	1.66	1.75	1.77	1.74	1.79	1.93	2.52
n_M	3	2	2	2	2	2	2	3

Table 11: Calculations for the dimensioning of the PV system

The required modules were recomputed separately for every month as can be seen in Table 11. It became apparent that two modules were needed for the months April until September for energy production. It was also evident that the array has to be provided with three up to four modules to maintain the required energy supply.

Phase 2: Installation of the ReeVolt storage system

Biberhof Sonthofen

As part of the implementation process, a 4 weeks pre-test with the ReeVolt storage system was performed. By order from eza!, the company Solux was responsible for pre-testing.

During the pre-test, several problems with the ReeVolt system became apparent, mainly:

1. Self-discharge of the batteries: locked batteries discharge about 30 % within 12 hours even if the ReeVolt system is turned off, i. e. no power input / output and no load.
2. Malfunction every few minutes, if one Enecsys inverter and one 100 Watt bulb (connected to the power input) is connected to the system. After 1-2 minutes, the system reboots. The Enecsys output rating is 480 Watt. The same malfunction appears, if two Enecsys inverters (connected in parallel) where used.
3. Complete discharge of the ReeVolt storage (power consumption until battery-capacity = 0 %). The battery inverter cannot create a network anymore. This leads to the situation that the PV inverter cannot be turned on. No power connection is available at Biberhof. Therefore, if a

complete discharge happens, only an external charging can restore the complete functionality of the system.

The conclusion and the recommendation of the company Solux were very clear. If issues one and two are only technical problems, which can be solved quickly, it could be possible to use the ReeVolt storage system for the designated purpose. But if issue 3 is not solvable, it would not be advisable to use this storage system.

As the mentioned problems could not be solved on the part of the manufacture WEMAG in time (project period), the responsible partner eza! decided to use a normal lead battery for the system at Biberhof fulfilling the expected purpose.

source: eza!, 2014

Fig. 7 Outside sockets and inside installed battery at Biberhof Sonthofen

In the end, this decision held an advantage. Unlike the Buchrainer Alpe, the Biberhof is not permanently managed (see chapter 2.1). If the Biberhof serves as an exchange station, it could not be guaranteed that the system would not be damaged by mishandling or vandalism. Instead of an exchange station, e-bikers can now charge their batteries via external sockets where people can plug in their (external) charger (see Fig. 7).

Due to the fact that the original idea of using second life batteries as a storage could not be realized at the BIberhof, the following explanations, results, simulations and conclusions refer solely to the Buchrainer Alpe.

Buchrainer Alpe Oberstdorf

By order from B.A.U.M. Consult, the regional specialist and master electrician Walter Fritz installed the ReeVolt storage system and extra PV modules at the Buchrainer Alpe. This decision was taken, because Mr. Fritz is a versed master electrician and he had installed the previous island system in the hut. In contrast to the Biberhof, no pre-test simulation was conducted. But due to different requirements, the combination of the system was a challenge. The ReeVolt storage needs 230 voltage, but the existing island system runs with 12 volts. The solution was to install an additional inverter. The extra benefit of this solution was, that additional chargers can be connected to the system.

Phase 3: Collection of data

At the test site in the hut in Oberstdorf, several problems appeared during the operation and data collection process. However, most problems could be solved promptly. The major problem was the high self-consumption rate of the ReeVolt system. It was calculated and measured to be around 60 W.

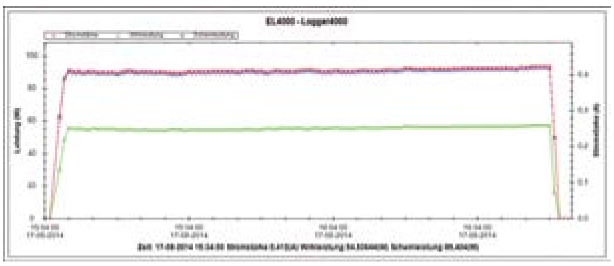
Consequently, if sun does not shine for three days, the ReeVolt system needs all the stored power to run its own system. This leads to a complete discharge of the ReeVolt storage. Thereafter, the ReeVolt system extracts the stored energy from the existing lead battery to recharge and to run its own system.

This was a crucial problem. Under these circumstances, an operation of the ReeVolt system throughout the estimated period could not be managed. The responsible partner B.A.U.M. Consult together with the local electrician and WEMAG tried to solve this problem. First, a software update seemed to be a solution. Unfortunately, this did not work. Changing hardware modules was considered, but it would have taken months to build them. In the end, all partners had to realize that no solution could be found in time for a successful full trial during the project period. WEMAG recognised this as a massive problem to be solved in the next product version of the ReeVolt storage system. According to latest statements from WEMAG, the self-consumption can be reduced by about 90 % down to 6 W. With such a storage the originally intended island system could have been built and successfully operated. However, with the given time constraints of the project that test could not be implemented.

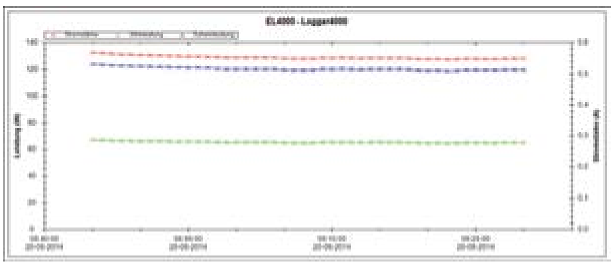
The project team decided to run a limited test with the sub-optimal storage to prove the principle feasibility. Only few weeks remained to reconsider the test phase. Despite the short operation time of the storage system, with the VOLTSOFT data logger it was possible to collect valuable data from the devices that were used daily by the tenants of the Buchrainer Alpe. Fig. 8 illustrates the different load curves of those devices. The data was analysed with the software VOLTCRAFT, which comes with the VOLTSOFT data logger.

A positive aspect was that no errors appeared during the operation time of the storage, e.g. no voltage drop or no undersupply of any device. These results show that it would be possible to run an island system via a second life storage as the ReeVolt storage was able to replace the lead battery during the test.

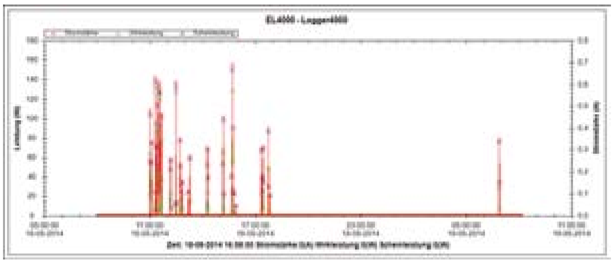
The graphs in Fig. 8 illustrate the load curves of the devices. The red line marks the current (Ampere), the green line the active power (Watt) and the blue line the apparent power (Watt).

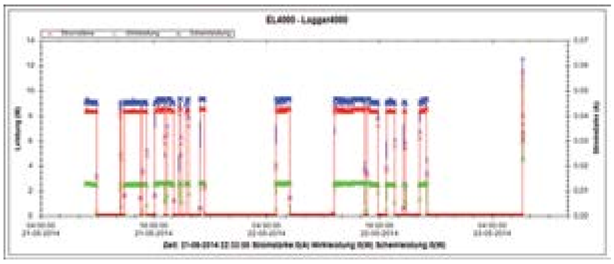


Load curve charging station



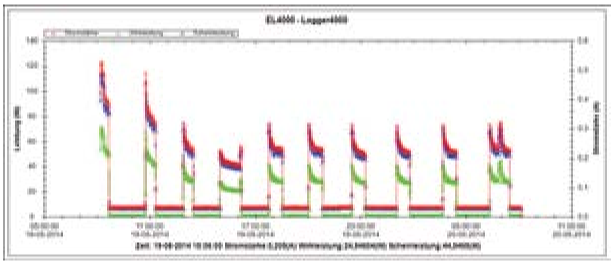
Load curve mixer/stirrer

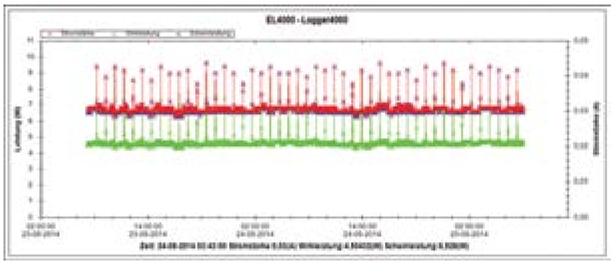




Load curve food slicer

Load curve sink and light





Load curve refrigerator

Load curve water filtration energy device

source: B.A.U.M. Consult, 2014

Fig. 8 Analyzed load curves of different devices

During the data collection process, only 14 Flyer batteries were available for the storage, because two batteries had been given to e-bikers. Therefore, data was collected based on the 14 available and charged batteries. Figure 9 illustrates the different charging levels of the batteries at the beginning (10.15 am) and at the end (03.15 pm) of the test phase. A positive effect was that no voltage drop or any undersupply of the devices could be detected. Furthermore, an exchangeable battery was charged during the operation time. This served as additional proof for the functioning of the ReeVolt system (see chapter 2.2.).

Initial charging levels			
60 %	60 %	60 %	X
70 %	90 %	90 %	X
100 %	100 %	100 %	100 %
90 %	90 %	100 %	100 %

Final charging levels			
40 %	40 %	40 %	X
50 %	90 %	70 %	X
40 %	50 %	50 %	40 %
50 %	40 %	60 %	60 %

source: B.A.U.M. Consult, 2014

Fig. 9 Charging levels of the 14 Flyer batteries in percentage

Phase 4: Calculations and Simulations

As mentioned in chapter 2.3, a calculation tool based on Excel was developed. Since an operation of the ReeVolt system throughout the estimated period could not be managed, the collected data of phase 3 were used to create different scenarios. The calculations are based on following parameters:

- Solar radiation: the solar radiation based on 15 minutes measures, which are normalized to 1 kWp. This data was adjusted for the calculations to account for the energy loss that always occurs in such a system.
- Load profile: the load profile summarizes all load at the Buchrainer Alpe. It can be divided into 2 major groups – demand and charging efforts.
- The self-discharge of the ReeVolt System is considered. The installed rated power of the devices can be adjusted individually.
- The charging cycles of the e-bike batteries are defined through the number of modules, the number of charging periods and the charging time.
- Period under review: March until September 2014; the period under review can be adjusted (hours, days, weeks, month).
- Self-discharge ReeVolt system: Through the locked/connected batteries, the self-discharge of the system was calculated. Initial situation = all 16 batteries are locked. For a smaller number, the self-discharge is calculated linear.
- Switch position ON of the ReeVolt storage = self-discharge 60 W;
- Switch positon OFF = self-discharge 24 W

Considering these facts, different scenarios were performed.

The first three scenarios represent different switch positions ON/OFF of the ReeVolt system. For these first three scenarios, the basic parameters are as follows:

- Period under review March until September 2014
- The load is measured in 15 minute intervals
- One extern E-Bike charging station, connected to a house network (230V)
- Altogether, 16 Flyer batteries within the ReeVolt system (considering self-discharge)
- 15 Flyer batteries used as steady batteries (not used as exchanged batteries for e-Bikes)
- 1 Flyer battery used as exchangeable battery
- number of charges per day

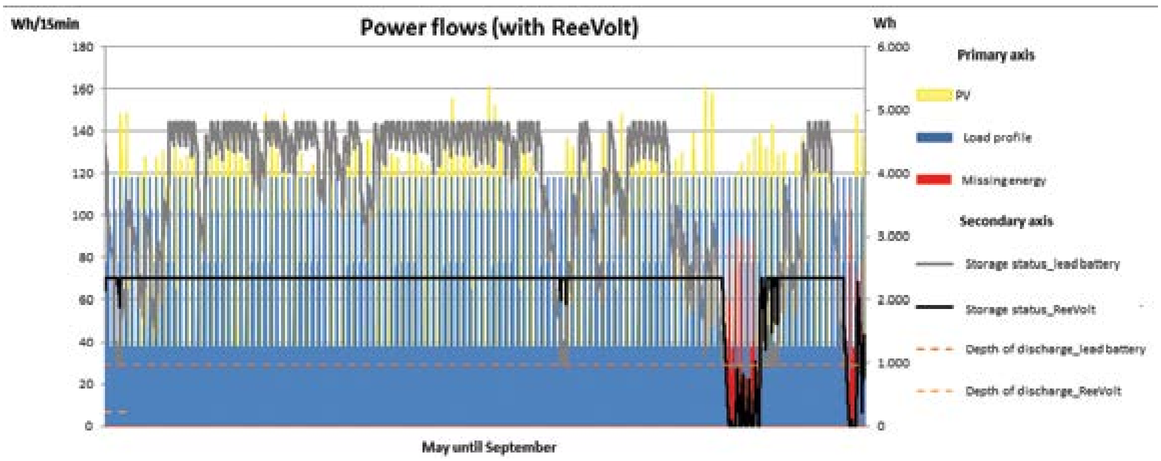
Scenario 1: ReeVolt storage all day an night ON

In scenario 1, the ReeVolt storage is always on – day and night. The switch position ON means 60 Watt of self-discharge for 16 slots. Considering these facts and the other parameters, a calculation was performed, the results of which are shown in Table 12.

Description	Power / Capacity	Unit	Amount of energy [kWh]	Other parameters	Nr
Generation PV	760	[Wp]	353.3		
Storage					
Lead battery	4800	[Wh]	103.7	charging cycles	21.6
ReeVolt steady (RV)	2343.75	[Wh]	16.5	charging cycles	7.0
Devices					
Load profile	476	[W]	275.4	self-discharge (RV)	**181.4**
E-Bike	166	[W]	116	Number of charges	**3.6**
Mixer	150	[W]	61		
UV Filtration	10	[W]	3		
Fridge	150	[W]	95		
Missing energy			**7.1**	Coverage rate	0.98
Solar energy unused			85	Rate of use	0.76
Solar energy used			353.3		

Table 12: Results calculations scenario 1

During the period under review, the amount of missing energy is calculated with 7.1 kWh. In Fig. 10 , the power flows of the hut network corresponding to the calculations in Table 12 can be seen. The blue line illustrates the load profile, the yellow line stands for the power generation of the PV modules. Based on this illustration, the self-discharge or rather the own consumption of the Ree-Volt system is mainly a problem in May and at the beginning of September. Although the storage is always ON, the missing energy has the lowest level within scenario 1.



source: B.A.U.M. Consult, 2014

Fig. 10 Power flows with ReeVolt system scenario 1

Scenario 2: ReeVolt storage ON from sunrise until sunset

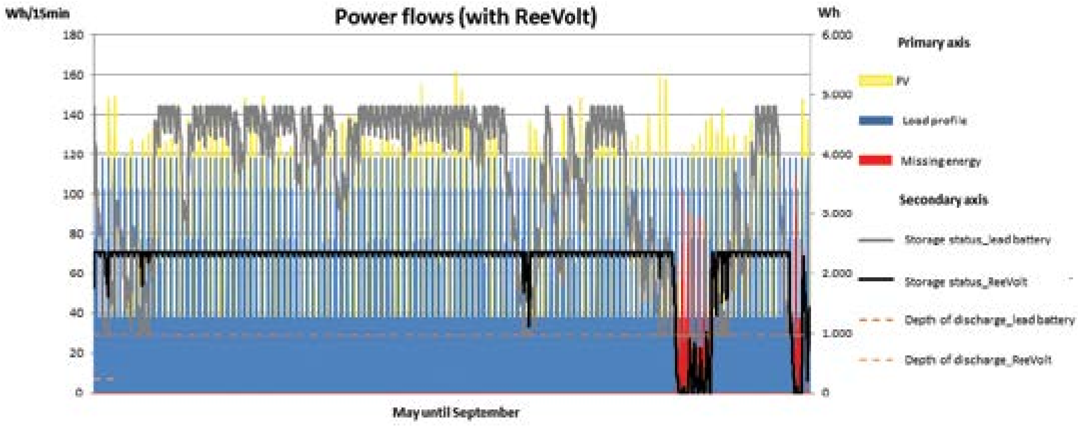
Within scenario 2, the ReeVolt system runs from sunrise (round about 5 o'clock) to sunset (round about half past nine). During this runtime, the switch position ON means 60 Watt of self-discharge for 16 slots. OFF in the rest of the day means that the system is in an inactive state and disconnected from the hut network. In this situation, the ReeVolt system has a self-discharge (reduced) of about 9.6 Watt. Considering these facts and the parameters the calculation leads to the results shown in Table 13.

Description	Power / Capacity	Unit	Amount of energy [kWh]	Other parameters	Nr
Generation PV	760	[Wp]	353.3		
Storage					
Lead battery	4800	[Wh]	108	charging cycles	22.5
ReeVolt steady (RV)	2343.75	[Wh]	25.7	charging cycles	11
Devices					
Load profile	476	[W]	275.4	self-discharge (RV)	**171.8**
E-Bike	166	[W]	116	Number of charges	**3.6**
Mixer	150	[W]	61		
UV Filtration	10	[W]	3		
Fridge	150	[W]	95		
Missing energy			**7.8**	Coverage rate	0.97
Solar energy unused			85.7	Rate of use	0.76
Solar energy used			353.3		

Table 13: Results calculations scenario 2

During the period under review, the amount of missing energy is calculated with 7.8 kWh. As a result, the coverage rate drops to 97 %. Concerning the reduced runtime of the ReeVolt system, the self-discharge decreased by about 5.3 %. An interesting fact is that the charging cycles of the ReeVolt system increases from 7 up to 11 charging cycles.

Similar to scenario 1, Fig. 11 shows the power flows of the hut network regarding the calculations in Table 13. The red line marks the missing energy. The blue line illustrates the load profile and the yellow line depicts the power generation of the PV modules. Also, the depth of discharge of the lead battery can be seen as well as the discharge of the ReeVolt system (dotted lines) and the ReeVolt storage status (black line).



source: B.A.U.M. Consult, 2014

Fig. 11 Power flows with ReeVolt system scenario 2

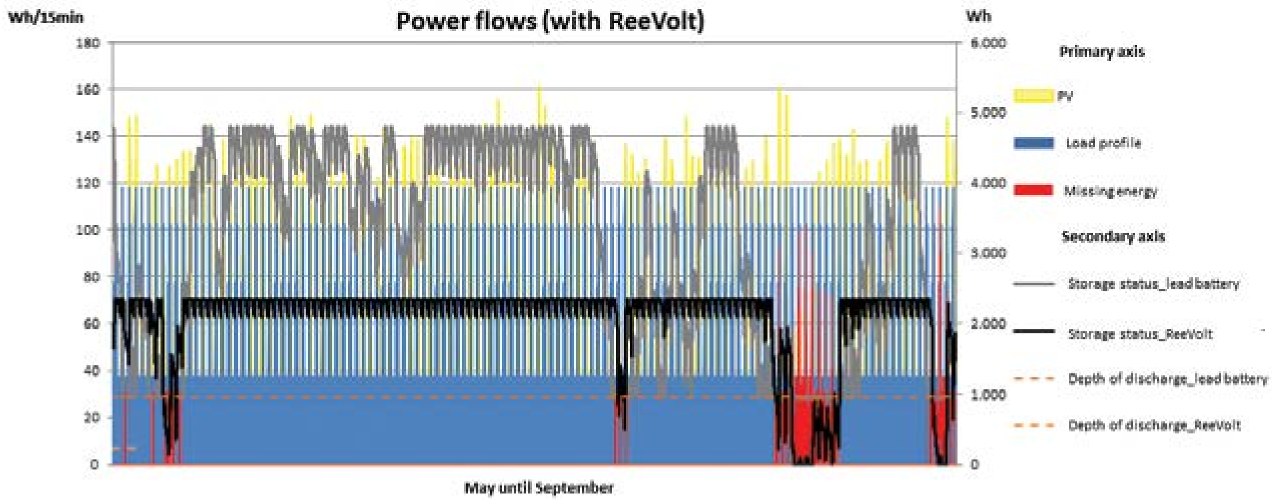
Scenario 3: ReeVolt storage electrically controlled considering solar radiation and charging process changeable batteries

Within simulation scenario 3, the ReeVolt system runs according to the solar radiation and the charging processes of the exchangeable batteries (if possible). Similar to the other scenarios, the switch position ON means 60 Watt of self-discharge for 16 slots. OFF means an inactive state and disconnection from the hut network. In this condition, the ReeVolt system has a self-discharge (reduced) about 26 Watt. Considering these facts and the parameters, the calculation leads to the results shown in Table 14.

Description	Power / Capacity	Unit	Amount of energy [kWh]	Other parameters	Nr
Generation PV	760	[Wp]	353.3		
Storage					
Lead battery	4800	[Wh]	115.5	charging cycles	24.1
ReeVolt steady (RV)	2343.75	[Wh]	55.8	charging cycles	23.8
Devices					
Load profile	476	[W]	275.4	self-discharge (RV)	**139.7**
E-Bike	166	[W]	116	Number of charges	**3.6**
Mixer	150	[W]	61		
UV Filtration	10	[W]	3		
Fridge	150	[W]	95		
Missing energy			**12.2**	Coverage rate	0.96
Solar energy unused			90.1	Rate of use	0.74
Solar energy used			353.3		

Table 14: Results calculations scenario 3

Despite the adapted operation of the ReeVolt system, the coverage rate decreases again to 96 %. The rate of use drops to 74 %. The amount of missing energy is calculated with 12.2 kWh from May until September. Although the self-discharge was reduced, the amount of missing energy increases. Compared to the results from scenario 1 and 2, the self-discharge decreased by about 23 %. This clearly supports dynamic operation of the ReeVolt system, but considering all factors, an operation 24/7 is assessed to be the best solution.



source: B.A.U.M. Consult, 2014

Fig. 12 Power flows with ReeVolt system scenario 3

Scenario 4: ReeVolt storage with adapted charging cycles of the e-bike batteries

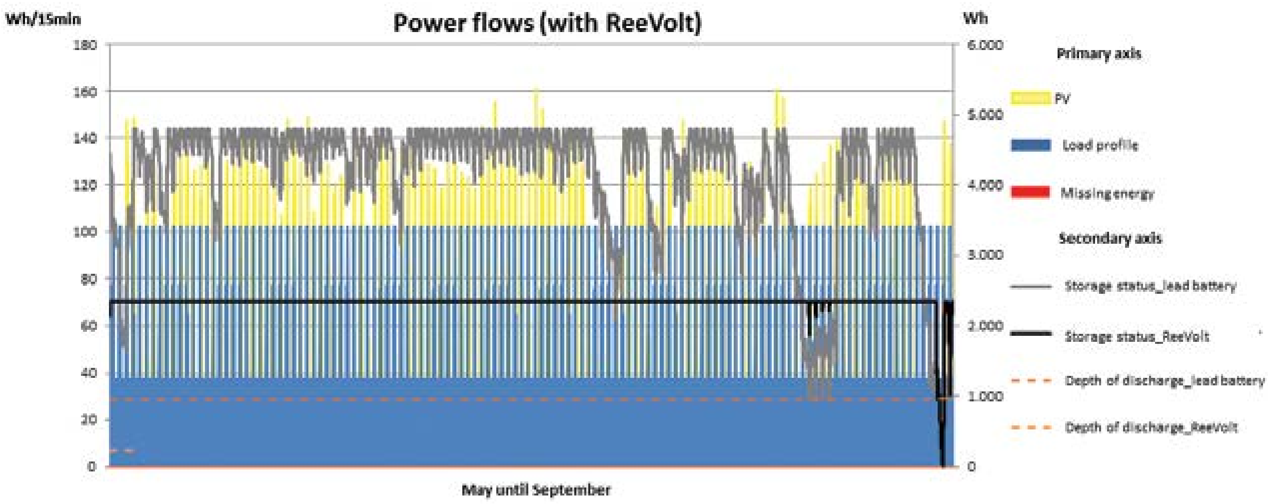
In scenario 4, all "lessons learned" are summarized. To reduce the amount of missing energy, the number of charges for e-bike batteries has been adjusted. That means that no external e-bike charging station is connected to the system. Only one Flyer battery can be used as exchangeable battery. This leads to a reduction of two charges for e-bike batteries per day (see Table 15).

Due to the adjustments, the amount of missing energy decreased to 0.4 kWh for the whole period (May until September). The coverage rate increased to nearly 100 %. However, the rate of use is only at 63 %. Certainly, from an economic point of view, there is still plenty of potential. By reducing the self-consumption as mentioned in phase 3, the rate of use could be increased.

Description	Power / Capacity	Unit	Amount of energy [kWh]	Other parameters	Nr
Generation PV	760	[Wp]	353.3		
Storage					
Lead battery	4800	[Wh]	108.7	charging cycles	22.6
ReeVolt steady (RV)	2343.75	[Wh]	5.1	charging cycles	2.2
Devices					
Load profile	414	[W]	224.6	self-discharge (RV)	**181.4**
E-Bike	104	[W]	66	Number of charges	**2**
Mixer	150	[W]	61		
UV Filtration	10	[W]	3		
Fridge	150	[W]	95		
Missing energy			**0.4**	Coverage rate	1
Solar energy unused			129.1	Rate of use	0.63
Solar energy used			353.3		

Table 15: Results calculation scenario 4

Similar to the other scenarios, Fig. 13 illustrates the power flows of scenario 4. The blue line illustrates the load profile and the yellow line stands for the power generation of the PV modules. The depth of discharge of the lead battery can be seen as well as the discharge of the ReeVolt system (dotted lines) and the ReeVolt storage status (black line). The red line would mark missing energy. But in this scenario all consumption needs can be fulfilled by the system.



source: B.A.U.M. Consult, 2014

Fig. 13 Power flows with ReeVolt system scenario 4

Phase X: Involving visitors and attracting e-bikers

source: B.A.U.M. Consult, 2014

Fig. 14 Folder distributed in the Buchrainer Alpe

In an ongoing effort, the project team together with the tenants of the hut informed visitors on the on-going pilot project. With a folder and a poster in the hut, the idea of the system was explained and various visitors have shown interest in this new technology.

MOVELO, the e-bike rental provider in Oberstdorf, referred to the new charging and swapping service in the Rappental. A sticker developed by **AlpStore** was added to the existing folders and maps and it could be proven that more e-bikers stopped by in the Buchrainer Alpe.

3 Conclusions

While due to severe technical problems the originally planned field test did not completely work out, still there were some interesting findings:

Battery system works but needs reengineering:

After overcoming few installation challenges (the storage was not built for standalone, offgrid purposes!) the ReeVolt system worked fine. However, self-consumption of the system was at 60 W and way too high for practical purposes. Towards the end of the **Alpstore** project, the system was undergoing a redesign and according to producer WEMAG the self-consumption is now down to a reasonable 6 W. For further implementations the lesson learnt is that self-consumption and self-discharging is a critical success factor.

Using 2nd life batteries is feasible:

During the short operation time (see phase 3 of chapter 2.4), the ReeVolt storage with 2nd life batteries completely powered the hut for an entire day. This could prove that the ReeVolt storage can guarantee an error-free operation of the inhouse network.

A system with exchangeable batteries brings flexibility and serves the purposes of e-bike charging:

While only some dozens of e-bikers used the new service, the tenants of the hut felt that a flexible system that allows for swapping as well as charging e-bike batteries could attract more customers for their gastronomic service. The modular ReeVolt system can easily adapt to demands that change over the tourism season.

ReeVolt system is too big for the purposes of the hut:

Scenario 4 shows that the extension of the storage capacity of the existing system is not really necessary. While the coverage rate was at about 100 %, the rate of solar radiation was at about 63 %. Consequently, only half of the sockets would be needed and the system proves to be too expensive for this purpose.

3.1 Follow-up plans

In general terms the tenants and the owner of the Alpine hut were very open to keep the reengineered version of the ReeVolt storage system. The prize could have been negotiated and was assessed as being in the range where the extra income from the e-bikers visiting the hut would outweigh it.

At the end of the project it turned out that this solution is obsolete. On short notice, it was announced that the Buchrainer Alpe as well as all other properties in the valley will be connected to a power grid that will be implemented soon. The grid will be built on the costs of the Bavarian state to power a radio station for mountain rescue service in a very distant part of the valley. The owners of the huts and other premises have been offered to connect to the grid more or less free of charge and willingly took this opportunity. So all attempts to implement way more cost effective island systems are no more relevant.

AlpStore's proof that 2nd life batteries are a sustainable alternative to new battery packs may have been a reason for actors in the Allgäu to enter into a new endeavour: together with an international consortium in the framework of a Horizon 2020 project called ELSA huge batteries will be installed to better manage the power grid and to secure supply of villages and city quarters in emergency cases.

3.2 Transferability to other Alpine regions

While for special reasons implementing the system in the Stillach- and Rappental is not feasible any more, other Alpine region may consider to establish such a solution. While building a grid in mountainous and scarcely populated Alpine regions is very costly, self-contained island solutions are cheaper and very reliable with today's technologies.

The idea of giving e-bike in the future also e-car batteries a second life may be one element in the energy and climate plans of Alpine cities and regions. It contributes to the goals of the European energy initiative to develop an "integrated roadmap" which takes into account all types of storage and links power grids to gas and heat grids as well as to the future mobility networks.

Oberallgäu, Germany
PV-Store plus home
Case study

Project Partners: AÜW, Public Power Utility Allgäu / eza!, Energy and Environmental Centre Allgäu

Authors: Carmen Albrecht, Felix Geyer, Nina Werner

Contacts: Carmen Albrecht, Felix Geyer

Case studies are contributing to AlpStore WP 6

Work Package 6 Responsible: EUROIMPRESA LEGNANO s.c.a r.l.

Lead Partner: B.A.U.M. Consult, Ludwig Karg, Patrick Ansbacher, Anja Lehmann

Abbreviations

AKW	Allgäuer Kraftwerke GmbH
AÜW	Allgäuer Überlandwerk GmbH
BefA	Beirat für die Begleitung der Energiezukunftsprojekte in der Region Allgäu
EEG	German Renewables Energy Act
EnWG	Energy Industry Act
Eza!	Regional energy-and-environmental-center
KfW	Kreditanstalt für Wiederaufbau
RE	Renewable Energies
PEESA	Potential of renewable and efficient power generation in the Allgäu region

1 Storage technologies for the region Oberallgäu, Bavaria, Germany - general frame conditions and objectives

In addition to the sustained expansion of renewable energy technologies such as hydroelectric, wind and photovoltaic systems, future storage technologies will be analysed and brought forward. In 2012, about 33 % of the electric energy consumed in the Oberallgäu (inclusive Kempten) was produced by renewable energy sources as visualised in figure 1.

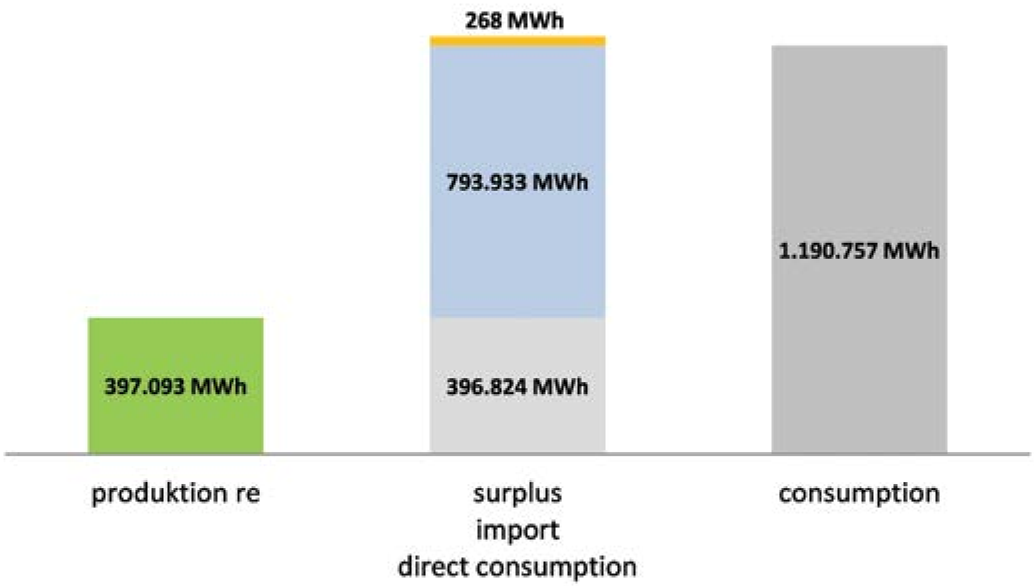


Figure 1: Scenario – present situation: energy balance - production, import, direct consumption and consumption; period 1 year (2011), [source: eza!]

However with a current renewable energy share of 33 %, the pilot region is importing a big quantity of energy, 793.933 MWh are still necessary to cover the annual consumption.

The latest analysed generation potential (that is based on the PEESA-study and extended by eza! with the results of the communal climate protection concepts) of electric energy is especially located in the photovoltaic and wind power sector. Currently, only 3 % of the wind energy potential (over 850.000 MWh per year) is already used. Although there are already large numbers of photovoltaic systems installed, the potential of the pilot region is still enormous. If the full technical potential was tapped, over 685.000 MWh per year would be generated by PV-systems. If the overall production potential of renewable energies was exploited, the district Oberallgäu would produce more electric energy than consumed, seen over the course of a year. The fluctuating generation of renewable energies – more or less production than direct consumption in a few hours of the year – causes an unsteady feed-in of power. If the production is higher than the consumption, there is a surplus of energy: in the Allgäu region of approximately 268 MWh/a (see figure 1). This oversupply on the one hand and the import of energy on the other hand causes network load and loss of power, with a growing share of renewable energies this issue is intensified. The regional produced regenerative energy current cannot be consumed directly at any time. If the current is not directly consumed, it is regionally transported to near consumption areas. In the next step, the remaining surplus current can be transported to high-consumption areas or stored. Thus, storage technologies should be developed, for example pumped-storage power plants and stationary/mobile battery storage systems. However, to cope successfully with the energy transition (against the background of regional added value and efficiency) there is no one solution, instead, a variety must be found:

- balance between climate and landscape protection;
- energy transition means systemic change; fluctuating renewable generation like PV or wind energy is not able to provide base load power;
- energy policy must be supported regionally, objective: balance of the energy economic triangle (security of supply, efficiency, environmental safety);
- sole use of solar and wind energy will not produce sufficient electric energy;
- Not only regional production units are necessary. It is rather useful and economically acceptable to use all the possibilities of regional balancing between production and consumption. It should be the objective to reach energy autonomy, meaning to have an identical financial value of energy consumption and generation over a year. In contrast, energy autarky means to be self-provider for 100 % for each moment in time.
- In addition to the construction of new generating capacity the possible options for the future security of supply are flexibility in production and consumption, network expansion and storage.
- Technically, many options are feasible, but crucial for the realisation are on the one hand the economies and on the other hand the social acceptance of the proposed projects.
- For economic aspects the following prioritisation is proposed:
  1. Generation and load management (flexible power plants and consumers);
  2. Energy transfer/transport: evolution of distribution and transmission network in order to transfer power regionally from rural to urban areas;
  3. Storages (temporary or seasonal);

1.1 Actual and future regional energy system

Figure 2 gives an overview of the installed capacity and produced energy in the investigation area Oberallgäu/Kempten in the year 2012. Also it shows the percentage of energy production in comparison to the total consumption in the investigation area:

	installed capacity [kW]	numbers	produced energy [kWh]	percentage of total consumption [%]
water	44.302	104	167.082.253	**14,2%**
wind	18.905	12	21.779.364	**1,8%**
photovoltaic	137.107	7.325	128.636.281	**10,9%**
biomass	10.612	54	50.434.045	**4,3%**
sewage gas	374	1	18.002.731	**1,5%**
natural gas	3.824	127	8.381.164	**0,7%**

Figure 2: Overview - installed power plants in the investigation area Oberallgäu/Kempten 2012, [source: AÜW GmbH]

In 2011, the private sector (blue), the economic system (red) and the transport sector (yellow) consumed 6.574.918,5 MWh/a of end energy in the pilot region. End energy includes heat (from fossil fuels, renewable energies and biomass) and electric energy

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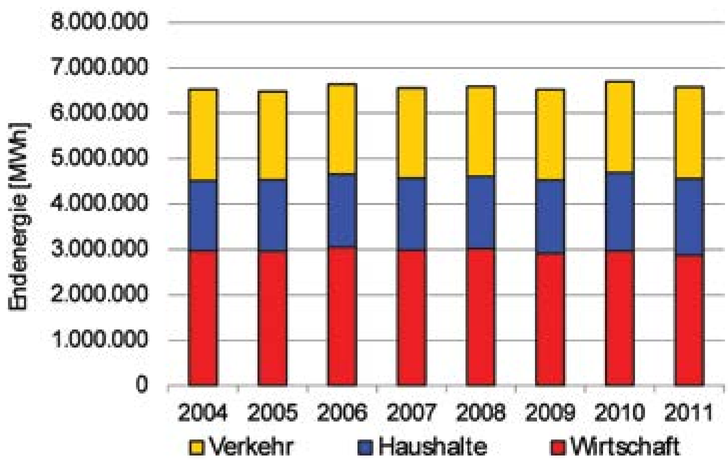


Figure 3: Final energy consumption by consumer groups: transport sector (yellow), private sector (blue), economic system (red), 2011, [source: eza!]

In the Oberallgäu region, the transmission system operator (TSO) Amprion is responsible for the security and stability of the energy supply system. The distribution system operator (DSO) AllgäuNetz GmbH & Co. KG (short AllgäuNetz) is predominantly in charge of the grid expansion. There are three different voltage levels of the power grid, high voltage (110 kV), mean voltage (20 kV, most common in rural and urban areas) as well as low voltage (0,4 kV). The high voltage power line is fed out at the 220/110 kV substations of Kempten Au and Rauhenzell, it is connected with the appropriate power line of the Lechwerke AG.

As mentioned before, the generation potential of electric energy is especially located in the fluctuating photovoltaic and wind power sector and the distribution grid is continuously extended. In addition, storage technologies become regionally important.

In this context, the following activities are conducted:

- Feasibility study of pump storage plants in the Allgäu region: 20 sites were examined, 3 are remaining (capacity of 60 to 100 MW for each site), the realization is planned to start in 2018 and the commissioning is scheduled for 2020/21.
- Thermal energy storage system: The Waste Management Association is installing a thermal energy storage system in addition to the district heat supply in Kempten, 33 MWh of thermal energy can be buffered.
- Power to heat: Insertion of a waste incineration plant in Kempten/Ursulasried as a secondary reserve for the district heat supply.
- Mobile (electric vehicles) and stationary batteries: various projects are running (IRENE, IREN2, econnect Germany, **AlpStore**) and further projects are planned.

1.2 Regulatory framework

The overarching German policy on renewable energy technologies and energy storage systems is the energy transition, a concept adopted by the federal government in 2010 and updated in 2011 after the Fukushima (Japan) nuclear catastrophe. The main targets of the German energy and climate policy are:

- Reduction of greenhouse gas emissions by 40 % until 2020, 55 % until 2030, 70 % until 2040, and 80-95 % until 2050 compared to the base year 1990.
- Reduction of primary energy consumption by 20 % until 2020, by 50 % until 2050.
- Increase of energy efficiency to 2,1 % per year in terms of the final energy consumption.
- Reduction of electricity consumption by 10 % until 2020 and 25 % until 2050 compared to the base year 2008.
- Reduction of heat demand in buildings by 20 % until 2020 and reduction of the primary energy demand in buildings by 80 % until 2050 compared to the base year 2008.
- Increase of the renewable share in the gross final energy consumption to 18 % until 2020, 30 % until 2030, 45 % until 2040, and 60 % until 2050.
- Increase of the renewable share in the final electricity consumption to 35 % until 2020, 50 % until 2030, 65 % until 2040, and 80 % until 2050.

The role of storage systems is described in the German energy concept as follows:

- Rapid expansion of renewable energy technologies: The generation from renewable energy sources shall become more adjustable and system services for network and supply security shall be provided. An increasingly flexible conventional generation park as well as energy storage systems shall balance the fluctuating generation from renewable energy technologies.
- Intelligent electric networks and stores: For the expansion and the system integration of renewable energies intelligent distribution grids are of major relevance. The amendment of the Energy Industry Act (EnWG) is paving the way for intelligent networks and stores.
- Present need for storage: The photovoltaic electricity generation in Germany at midday has reached a level, which leads to a strong offer and subsequent reduction of spot market prices for electricity. This reduces the need for and profitability of pump storage systems and power plants. However, it is obvious that this situation will not persist and pump storage systems, or

more generally storage systems of any kind, and flexible electricity power plants will be needed very soon at much larger scale than ever [source: **AlpStore** Whitebook STORM].

- Future need for storage: Beyond a threshold of 40 % RE storage systems will be significant for the operation of transmission grids. To be prepared for a RE penetration of 80 % and beyond, there has to be extensive investigation of storage technology and deployment. Storage will not be needed in Germany until about half of the electricity will be provided from RE sources, even if the major part of the RE electricity is provided by wind power and PV-plants. Hence, there will be a much larger need for long-term than for short-term storage for which many options and alternatives exist [source: **AlpStore** Whitebook STORM].

In the pilot region the "Regional Planning Association Allgäu (for region 16)" decides on the regional plan, its amendments and discusses the interests of its members. Besides Oberallgäu and Kempten the region 16 contains the areas: Lindau, Ostallgäu and Kaufbeuren.

After the decision of the nuclear power phase-out until 2022 in Germany, a perpetuation of a chapter dealing with the utilization of wind power in the regional plan has been decided in June 2013, which is still an ongoing process. The targets are the revealing of possible sites for wind power plants and the local and autonomous implementation of the energy transition and the utilization of wind power adapted to regional conditions.

In 2011, the policy makers of the Oberallgäu region have made ambitious adjudications, the council decided to generate 70 % of the annual regional electricity consumption by renewable energy sources. Since then, the respective municipalities and counties are continuously working on climate protection concepts which analyze the current status and possible actions – in cooperation with the regional energy-and-environmentalcenter eza!.

2 Pilot project PV-Store^plus house

The main focus of the pilot project is the storage of solar energy, which is generated by photovoltaic plants installed in private households. Six regional households were equipped with stationary battery systems to balance intermittent PV-production.

2.1 Characteristics of the field test

For the **AlpStore** project the investigation area was defined on the county Oberallgäu and the town Kempten, this area is mainly supplied by the Allgäuer Überlandwerk GmbH (AÜW) and the Allgäuer Kraftwerke GmbH.

The cognition of the PEESA-study (high generation potential in the wind and photovoltaic power sector) regionally causes a steady building of additional PV-capacity. Due to massive loads in times of high production rates of renewable energies, energetic recovery to the higher-level national power grid appears up to 50 times per year for several hours (about 70 MW). As alternative or amendment to the expansion of the grid, battery storage systems installed in private households could help to stabilize the voltage grid and provide balancing power.

In the pilot region lithium-ion batteries as well as lead-gel batteries were tested with the following characteristics: **short-term temporary storage**, compatibility to PV-plants, electrochemical technology, already available on the market but new technology, operation in private households (less legal barriers, reasons of practicability).

The purpose of the pilot project was on the one hand **the examination of the functionality of the battery system**, on the other hand the **measurement of the self-sufficiency rate** depending on the consumption profile. A further objective was the formation of **expertise to offer customers innovative products** linked with professional advice as well as the optimization of self-sufficiency and **calculation of profitability**. Finally, the pilot partners AÜW and eza! wanted to contribute with expert knowledge to the current political discussion. Based on the gained experiences, business models and concepts for the future energy supply with special reference to the objective of energy efficiency will be developed.

In order to regionally implement the objectives and to realize the project, local stakeholders were integrated (recognition by the general public, confederates, facilitator, discussion partners and multipliers). The BefA (‘Beirat für die Begleitung der Energiezukunftsprojekte in der Region Allgäu’) is a regional network of actors and stakeholders (e.g. city of Sonthofen) for the attendance of projects dealing with the energy future in the Allgäu region, they meet one to two times per year.

About 80 % of the PV-systems are installed in the low voltage grid. With the increasing expansion of PV, the distribution network as well as lines and transformers reach their load limits. Voltage limits may be exceeded, but in order to not limit the further installation of photovoltaic systems, the low voltage network has to be expanded, which is in duty of the grid operator. According to § 12 EEG (date: 08/2014) the grid-operators are “at the request of feed-in, responsible to immediately optimize their networks in accordance to the state of art, strengthen and expand in order to ensure the transmission and distribution of electricity from renewable energy sources”. As alternative or amendment to the expansion of the grid, local network storages could help to stabilize the grid. But battery storages are still very expensive and the operating battery storages installed in private households do not contribute to the grid stabilization. The reason for this is the discrepancy between the interests of the private battery owners (aim: high autarky-degree; optimization of the single household) and the low voltage grid relief. In the following figure 4, the different interests are visualized: on the left side the battery storage does not contribute to the low voltage grid relief; the midday peak load generated by the PV-plant is directly fed into the grid. The right side shows the optimal contribution of storage systems to the grid relief.

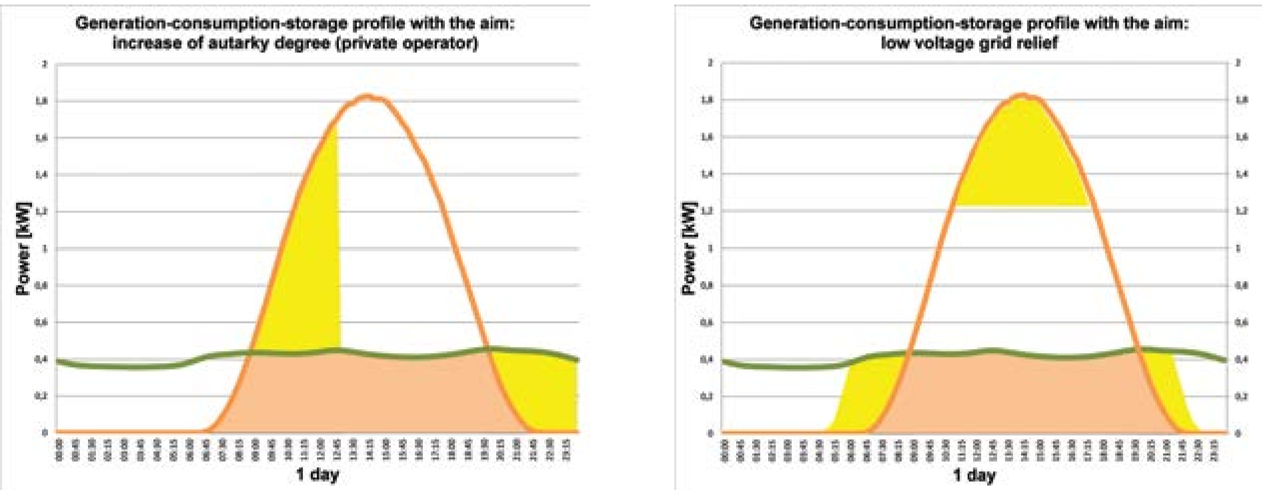


Figure 4: Left: Generation-consumption-storage profile with the aim: increase of autarky degree (private operator); Right: Generation-consumption-storage profile with the aim: low voltage grid relief; green: household load profile (summer), yellow: storage charging and discharging, orange: PV-generation profile, light-orange: PV-direct use, [source: AÜW GmbH]

In order to combine both generation-consumption-storage profiles and the mentioned aims (autarky degree and grid relief), it has to be taken into consideration that the control of decentralized batteries is technically demanding, expensive, questionably in reference to the privacy policy and the tariffs are not existing yet.

2.2 Storage technologies and frame conditions

The choice for the storage technology tested in the **AlpStore** pilot project fell on electrochemical short-term temporary storage systems, which are compatible to PV-plants, already available on the market but a new technology. The storage accumulators of AÜW and eza! are stationary batteries, especially small sized batteries (lithium-ion and lead-gel) for operation in private households.

Lithium-ion batteries are considered to be the storage technology of the future. They have the following characteristics:

- use in mobile telephones, laptops, electric vehicles;
- high energy density of up to 200 Wh/kg;
- space-saving;
- cycle-resistant;
- high number of charging cycles;
- no maintenance necessary;
- no use of poisonous substances;
- self-discharge ~ 1% per month;
- depth of discharge: between 60 to 90 %;
- expensive initial investment;
- necessity of rare earths;

Lead-gel batteries have been used as storages for more about three decades and can be considered as established, proven and relatively cheap storage technology [source: **AlpStore** Whitebook STORM]. They have the following characteristics:

- use as starter battery and uninterruptible power supply;
- energy density of 20-35 Wh/kg;
- not cycle-resistant;
- passable number of charging cycles;
- heavy metal lead is ecologically harmful;
- self-discharge ~ 1% per month;
- depth of discharge: 50 %;
- lower initial investment;
- recyclable;

For the pilot project, AÜW selected two battery storage systems which are based on lithium-iron-manganese-phosphate (Knut) and two based on lithium-iron-phosphate (Sonnenbatterie), eza! chose two based on lead-gel (Solux/Die AllgäuBatterie):

Manufacturer	Knubix GmbH	Sonnenbatterie GmbH	Solux GmbH and Die Allgäu Batterie GmbH & Co. KG
Storage technology	$LiFeMnPO_4$	$LiFePO_4$	Lead-gel
Nominal capacity [kWh]	5,5	10,1 and 20,4	9,6
DoD (depth of discharge) [%]	80	70	50
Usable capacity [kWh]	4,4	7,1 and 14,3	4,8
Connection	3-phase	1-phase	1-phase
Coupling	AC	AC	AC
Discharge power [kW]	7,5	4,5 and 5	4,6
Charge power [kW]	1,6	4,5 and 5	5,28
Number of charging cycles	3.000	5.000	2.500
Isolated operation	yes, grid supporting	yes	yes

Figure 5: Chosen battery storage systems by AÜW and eza!, [source: AÜW GmbH]

For the selection of the six pilot households the following prerequisites were determined:

- annual power consumption: about 4.000 kWh/year (the average annual power consumption in the Allgäu region);
- installed PV-plant with power of 4 to 10 kWp;
- initial operation of the PV-plant in the time period between April to December 2012 (there is no storage sponsorship for those customers);
- AÜW or AKW customer;
- additional space in the meter cabinet for the generation meter;
- sufficient WLAN and funk coverage in the basement;

2.3 Research design and schedule

For the implementation of the regional pilot project the following phases were defined and executed in a schedule as shown in figure 6:

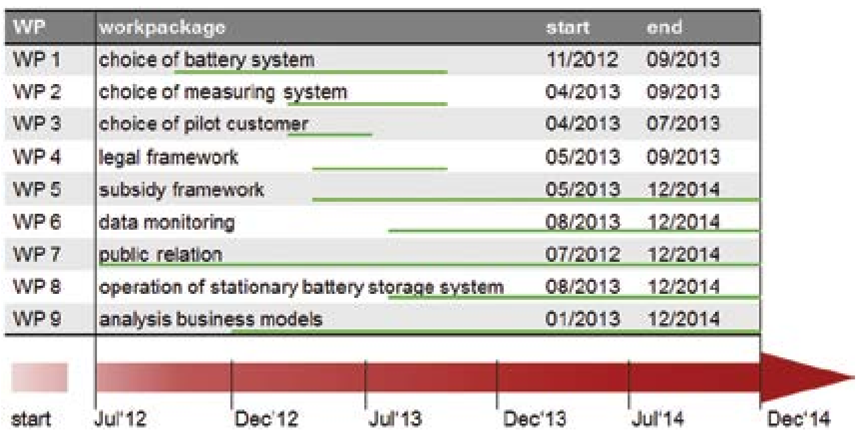


Figure 6: Work plan of the AlpStore pilot implementation PV-Store plus house, [source: AÜW GmbH]

Research design - storage operation

In the context of the project **AlpStore**, it was planned to install battery storage systems in homes that generate electricity with a photovoltaic system. In addition, the households should get an e-bike and e-scooter. Furthermore, the energy balances were calculated and the design of the system was optimized in reference to self-sufficiency and calculation of profitability. Moreover, the following energy data was logged and analyzed:

- Determination of autarky degree in dependence of the PV-plant, the battery storage system and the self-consumption of the pilot households.
- Autarky degree in comparison with other competitors and compared to the theoretical analysis of the HTW Berlin. Figure 7 shows the estimation for the autarky degree of a single family household by norming the annual power consumption.
- Calculation of the self-consumption quota (self-consumption of the PV-production di-vided by the generation of the PV-plant).
- Determination of the charging cycles.
- Analysis of the peak loads of the pilot households.
- Measuring and determination of the technology efficiencies and the power losses caused by the inverters.
- Calculation of the cost effectiveness of the battery storage systems (pilot house-holds).
- Examination of the load shift of the battery storage system.
- Compatibility test of storage battery data and scalar data (PV-production, net feed-in, net coverage).

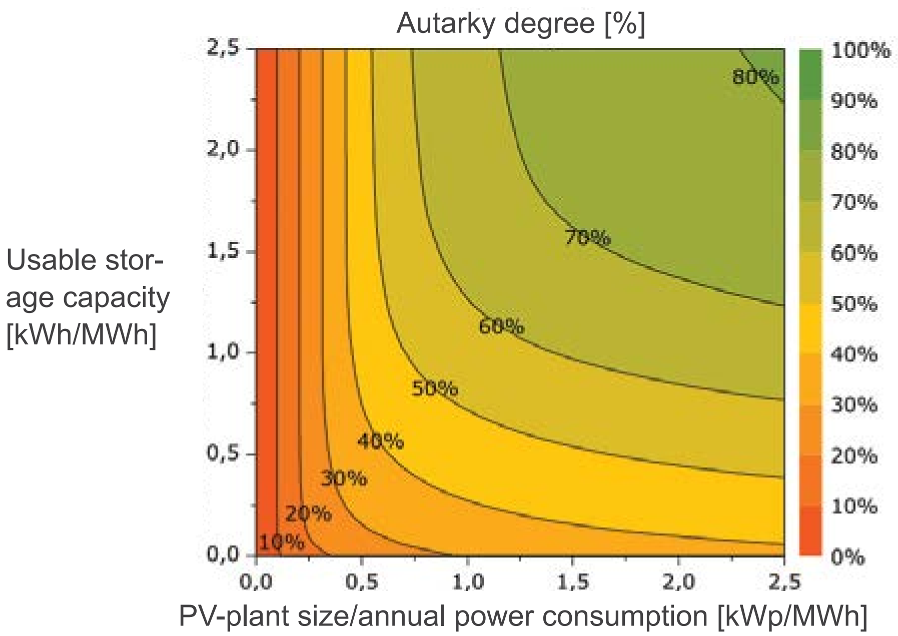


Figure 7: Energetic system sizing, [source: HTW Berlin]

2.4 Implementation process

(1) Choice of battery system

The first step was a market research on available battery storage systems. Thereby the main cognition was that the request for solar battery storages is satisfied by a multiplicity of companies from the most varying branches (about 40 manufacturers) with different products (40 – 45 originary systems with diverse battery dimensioning). About one half is working three-phase, the other half single-phase. Most of the systems are AC-connected to the home grid, a few in the DC-power circuit previous to the inverter. Storage systems can be discussed by many criteria but they are hard to compare.

In order to find sponsors for the pilot project, the project partners sent out requests to 22 battery manufacturers in Germany. The local companies Knubix GmbH, Sonnenbatterie GmbH, Solux GmbH and Die Allgäu Batterie GmbH were chosen to participate in the project and to offer customers battery systems for rent/purchase. After termination of the project, the Knubix customers decided to uninstall and return the storages, the Solux customers decided to buy the systems for the residual value.

(2) Choice of measuring system

Special measure concepts were developed and installed in the pilot households in order to uniformly gain the data base for monitoring and analysis. In addition to the installation of stationary battery storages the six pilot households of the AÜW and eza! were each equipped with a scalar modem (communication unit) and two electrical meters; one bidirectional meter and one generation meter. Thus, it was possible to visualize the volume of purchased electricity, feed-in electricity and power generation.

(3) Choice of pilot customers

The choice of the pilot customers occurred under the prerequisites mentioned in chapter 2.2. In order to select two eza! pilot households in Sonthofen, in April 2013 an article in the local newspaper “Der Sonthofer” was released. Consequently, 14 interested private persons applied. From those, 2 households were selected by the administration of Sonthofen. AÜW directly contacted 84 specific customers. In the aftermath, 4 pilot households were selected to install two different solar battery systems (see figure 8). The battery storage systems were implemented between August and October 2013.

	1	2	3	4	5	6
Implementing	Aug 2013	Aug 2013	Sep 2013	Oct 2013	Oct 2013	Oct 2013
Nominal capacity	5,5 kWh	5,5 kWh	10,2 kWh	20,5 kWh	9,6 kWh	18,0 kWh
Using capacity	4,4 kWh	4,4 kWh	7,1 kWh	14,3 kWh	4,8 kWh	9,0 kWh
Phase	3 phase	3 phase	1 phase	1 phase	1 phase	1 phase
Coupling	AC	AC	AC	AC	AC	AC
Technology	LiFeMnPO4	LiFeMnPO4	LiFePO4	LiFePO4	Lead-gel	Lead-gel
Charging cycles	3.000	3.000	5.000	5.000	2.500	2.500
Discharge power	7,5 kW	7,5 kW	4,5 kW	5 kW	4,6 kW	4,6 kW
PV-plant	4,4 kWp	5,6 kWp	6,75 kWp	3+6 kWp	4,9 kWp	9,3 kWp

Figure 8: The chosen battery storage systems of the six pilot households, [source: AÜW GmbH]

In order to implement electromobility in the pilot project, the two pilot households in Sonthofen was offered an e-scooter. Moreover, the other four pilot households had the possibility to test an electric car for one week.

(4) Legal framework

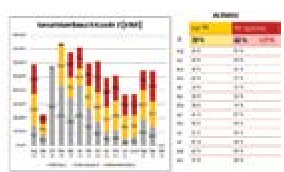
The legal framework was settled by an agreement between the project partners (AÜW and eza!) and the pilot households. Two pilot households got a subsidy for the purchase of the battery storage systems (option Sonnenbatterie). The other four pilot households could use the storage systems for free (option Knubix/Solux); the project partners covered the leasing fees during the project period. In return for the subsidy, data access was given to the project partners and the permit to use all relevant information for the project, public relation and to disseminate the results to experts and interested general public. The pilot households signed a data privacy statement.

(5) Subsidy framework

The KfW subsidy for battery storage systems exists since 01.05.2013. It funds solar storage batteries which are acquired in connection with a newly built photovoltaic plant and existing PV-plants taken into operation after 31.12.2012 coupled with a solar storage battery within six months.

The maximum capacity of the PV-plant is 30 kWp, it has to feed-in the produced electricity completely or partly (no support for island plants). The complete system (PV-plant and battery system) will be supported with 600 € per kWp, then the PV feed-in is limited to 70 % of the PV-plant power.

(6) Data monitoring



The battery storage systems are monitored and evaluated – monthly and over one calendar year. The PV-production, self-consumption, feed-in into the grid and the status of the battery were constantly monitored via web-portals. The evaluation revealed how effective the storage systems worked and the real benefits for the costumers. Furthermore, the internal storage-system data was verified by comparison with the data of the scalar modem.

Over the period of an entire year the full charging cycles of the battery systems and the consumption profiles (grid demand and self-production in comparison to the standard load profiles) of the customers were evaluated.

(7) Public relation

The sensitization of publicity about the necessity of storage technologies as amendment for fluctuating renewable energies was realized by diverse lectures in the context of exhibitions and course of lectures. Thereby, the regional potential of different storage technologies was presented as well as the cognitions gained in the pilot project **AlpStore**. Furthermore, a few press articles have been published in local newspapers and the AÜW customer magazine regularly reported on the project progress.

(8) Operation of stationary battery storage system

In context of the pilot project **AlpStore**, the implementation of the battery storage systems started in autumn 2013 and they were operated and monitored over a whole year until No-vember 2014. AÜW took over the first level support for the battery systems. Further cognitions gained in the operating phase are explained in the following chapter.

(9) Analysis of business models

Beyond the pilot project, the realization of battery storage systems requires profitability of the complete system; an interesting fact for consumers, energy agencies and energy suppliers. The cognitions gained in the pilot project are used for analyzing different profitability scenarios with the aim of providing a customer-friendly-all-in-one package (battery system, maintenance, installation, visualization, grid connection, residual current, energy consulting and regional value).

Deviations towards objectives of the pilot project

- In the pilot project, the connection of e-mobility with battery storage systems was put in the background due to small storage capacities.
- At this time, a customer-friendly-all-in-one package cannot be offered because the point of profitability of battery storage systems is not met yet.

Main outcomes and benefits

Technical findings

Important evaluation parameters for battery storage systems are the autarky degree and the self-consumption rate of the household. The latter describes the amount of self-consumed solar energy compared to the production of the PV-plant. The autarky degree reveals the independence of the power grid and the utility. Both parameters are being influenced by dimensioning of PV-plant and storage, choice of storage and consumption patterns.

Concerning theoretical assumptions, an average 4-persons household (electricity consumption: 4.500 kWh/a, PV-plant size: 5 kWp, usable storage capacity: 4 kWh) can raise the self-consumption rate up to 30 % by putting a PV-plant into operation, and up to further 30 % by installing a battery storage system [source: Fraunhofer ISE, HTW Berlin, BSW-Solar e.V.]. These statements are being confirmed by the results of the pilot project PV-storageplus house (see following figures)

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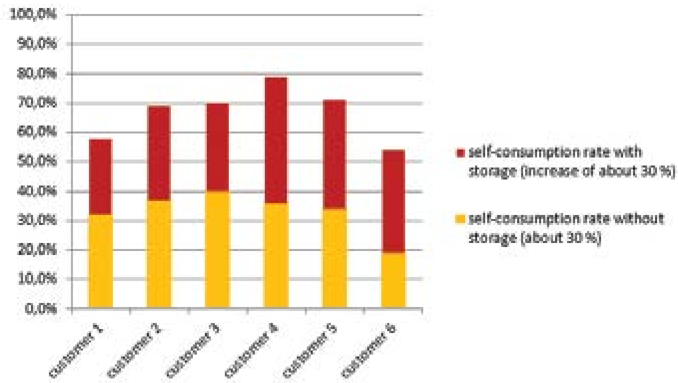

Figure 9: Self-consumption rate of the 6 pilot households without (yellow) and with storage (red), [source: AÜW GmbH]

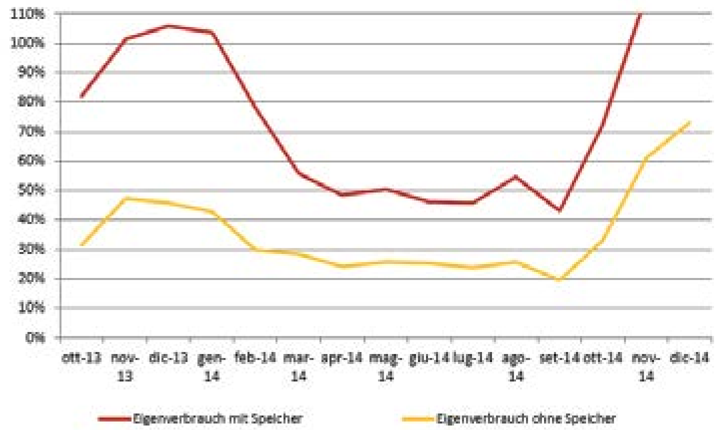

Figure 10: Self-consumption rate of a customer with lead-gel storage, [source: eza!];
Self-consumption rate without (yellow) and with storage (red);

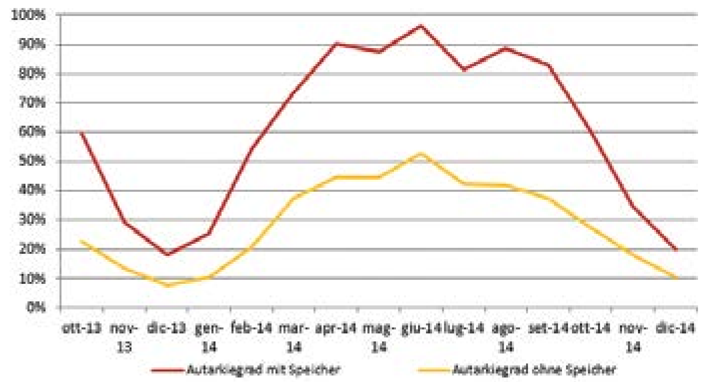

Figure 11: Autarky degree of a pilot customer with lead-gel storage, [source: eza!];
Autarky degree without (yellow) and with storage (red);

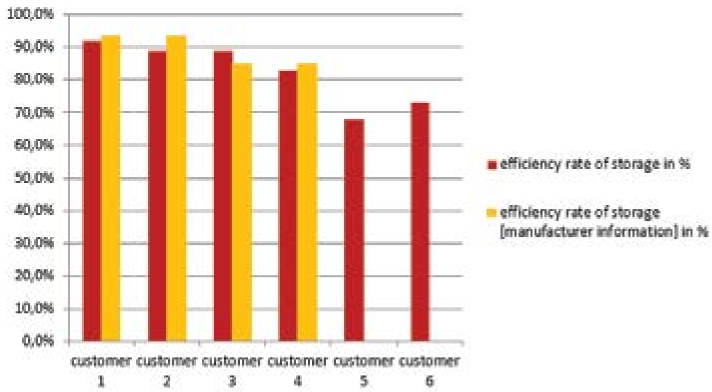

Figure 12: Efficiency rate of the tested storage systems, [source: AÜW GmbH]

The efficiency rates of the lithium-ion systems (customer 1, 2, 3, 4) are as far as possible conform to the manufacturer information, they are varying from 83 to 93,5 %. The lead-batteries show efficiency rates from 68 to 73 %, manufacturer information about their efficiency rate is not available.

In the expertise "economic feasibility of battery storage systems", the German Leipziger Institute for Energy assumes 250 charging cycles of lithium-ion systems per year. The analysis of the pilot project data results in about 270 charging cycles per year; new storage systems show an upward trend.

A further observation of the analysis was that the data of the scalar modem is not consistent with the data of the battery system, which doesn't include the self-consumption of the storage (deviation of about 60 W).

A final technical conclusion is that battery storage systems are marketable and functional, except for childhood diseases (e.g. triggering of short blackouts in households).

The topic battery storage systems is very complex, the different models can be discussed by many criteria (see following figure), but they are hard to compare. The overall efficiency is highly dependent on the consumption patterns and the requirement of the households. Storage systems, which are grid disconnected are about 2.500 – 3.000 € more expensive than grid connected systems. This has direct impact on the profitability.

Complexity of battery storage systems	
Type of battery	Lithium-Ion or lead-gel
Coupling	AC or DC
Phase	1 or 3
Operation mode	Grid connected or grid disconnection
Capacity	Usable or nominal capacity
Unloading capacity	Which peak power can be covered?
Loading capacity	How fast is the storage system fully charged?
Three-phase-current capable	Important for heat pumps
Charging cycles	How often can storages be charged and discharged?

Figure 13: Complexity of the subject battery storage systems, [source: AÜW GmbH]

Economic effects

When analyzing the economic potential, the key parameters are the battery- and power price development, the method of financing, replacement investment, consumption patterns, economic conditions for the energy sector, feed-in rate and currency fluctuations. The factors consumption pattern, economic conditions for the energy sector, feed-in rate and currency fluctuations are hard to calculate. Thus, for the calculation of profitability a complex system is revealed.

Since the inception of the KfW-subsidy for battery storages, many actors enter the market. In the middle of 2013 there were about 41 battery storage manufacturers with an average system price of 2.384 €/kWh, on year later there are about 44 manufacturers with an average system price of 2.111 €/kWh (minimum: 1.414 €/kWh, maximum: 3.594 €/kWh) [source: PV-Magazine June 2013, June 2014].

The price per usable battery capacity [€/kWh] is mainly dependent on the following parameters:

- Lead or lithium-ion technology;
- Usable capacity [kWh];
- Number of phases (1 or 3);
- Charging cycles per year;
- Life-time;
- Economies of scale;

In near-term it is expected, that the price per usable battery capacity will fall to 1.500 €/kWh, in medium-term to 1.000 €/kWh and long-term to 600 €/kWh [source: PV-Magazine June 2013].

For the economic evaluation of battery storage systems it is necessary to make different assumptions and forecasts. The following scenario is simplified, the maximum KfW-subsidy of 3.000 € is included.

Zyklen pro Jahr	250
Durchschnittspreis pro kWh Nutzkapazität Li-Ionen Speicher	2.000 €/kWh
Nutzkapazität im Beispiel	5 kWh
Kosten Beispielspeicher - max. Förderung 3.000 €	10.000 € 7.000 €
Betrachtungszeitraum	20 a
Gespeicherte Energie im Betrachtungszeitraum	25.000 kWh
Preis der gespeicherten Energie pro kWh (7.000 € / 25.000 kWh)	28 €Ct/kWh
Stromgestehungskosten PV	13 €Ct/kWh
Energiepreis (gesamt) (28 €Ct/kWh + 13 €Ct/kWh)	41 €Ct/kWh
Energiepreis heute	27 €Ct/kWh

Figure 14: Simplified feasibility calculation, [source: Leipziger Institute for Energy];

Assumptions:

cycles per year: 250;

average battery price per kWh: 2.000 €/kWh;

usage capacity: 5 kWh;

initial investment for battery storage: 7.000 € (inclusive financial sponsorship of 3.000 €);

review period: 20 years;

stored energy during the review period: 25.000 kWh;

Calculation:

price for the stored energy (7.000 €/ 25.000 kWh):

28 €ct/kWh;

electricity generation costs PV: 13 €ct/kWh;

total energy price per stored kWh

(28 €ct/kWh+13 €ct/kWh): 41 €ct/kWh;

actual energy price: 27 €ct/kWh;

The simplified calculation of profitability shows, that the energy price per stored kWh (41 €ct/kWh) is higher than the current energy market price (27 €ct/kWh). Under the assumed conditions the profitability is given with a battery price of 1.000 €/kWh (inclusive KfW-subsidy) and 700 €/kWh (without KfW-subsidy). With decreasing battery prices, business models will be conceivable. Currently, the project partners watch the development of the battery storage market.

Environmental impact

The mobility sector hast some studies about the ecology of battery storage systems, which compare the environmental impact of electric and conventional vehicles. Mostly, the amount of grey energy for the vehicle production and the CO_2-emission (gCO_2/km) in the driving mode are analyzed. By replacing fossil fuels with regenerative power, electric vehicles have an ecological benefit.

The ecological benefit of stationary battery systems is not easy to detect. The PV-generated electric power is partly directly consumed; the surplus power is conducted to other consumers. By installing battery storage systems, the transport route of renewable power is reduced. The increasing expansion of renewable energies results in grid load, consequently the shutdown of renewable generation plants comes under discussion. Storage systems can prevent the shutdown of renewable generation plants and lower the production share from fossil fuel plants, thus the storage systems offer environmental benefits.

For the manufacturing of lead-gel batteries an energy expenditure of 915 MJ per kWh is necessary, e.g. for the production of the battery system (18 kWh) installed in the pilot household in Sonthofen about 4.554 kWh were required. In order to redeem this amount of energy with a storage system (usable capacity of 9 kWh) about 500 to 600 charging cycles are necessary. Lead-gel and lithium-ion systems outnumber this amount of cycles 4 to 8 times.

A pilot household equipped with a battery storage system achieves a reduction of about 20 tons CO_2 by reducing the own electricity procurement.

Social benefits

A further objective of the pilot project was the targeted development of know-how for energy consulting services for citizens and municipalities. Besides a building- and heating system-check a so called solar-check was evolved. Private households are visited with the objective to inform about the potential use of solar thermic and photovoltaic plants. With the help of a standardized checklist the on-site circumstances (roof orientation and – pitch, existing plant technology, consumer profile) are considered and the possibility of PV-installation in combination with a battery storage system is inspected. The checklist was developed within the pilot project and six energy consultants were intensively trained, by campaigns they offer this service to municipalities in the Allgäu region.

Furthermore, the project partners intensively concentrated on the topic battery storage systems. By having a close customer contact, feedback and experience was generated, also in regard to the prospective development of business models and customer services.

Beyond the pilot project it is to say that there are some reasons for battery storages. From the customer perspective the self-consumption, the autarky degree and thus the regional added value can be increased.

With an intense expansion of battery storage systems and the private consumption privilege, the grid infrastructure costs will be split by a consumer collective, which is becoming increasingly smaller. Moreover, the power price will rise and thus, the solidarity principle will be weakened. From the economically point of view, this is disadvantageous.

The current German energy market model does not allow a grid supporting operation of battery storage systems, due to an interest conflict between grid operator and end customer.

Conclusions

Regional potential of the tested local options

The cognition gained during the pilot project is also relevant for further activities related to the energy future in the region. The result of a bachelor thesis (worked out within the **AlpStore** project) supposes that there is a potential of 17.200 private households (annual consumption of about 71 GWh) in the investigation area with a usable roof area for PV-plants connected to stationary batteries. The capacity per stationary battery will be 8-10 kWh that would produce a storage potential of 150 MWh/a. This covers 0,000362 % of the storage demand in 2022 with a share of 70 % RE and 0,000730 % of the storage demand in 2050 with a share of 150 % RE. Thus, further storage technologies are necessary.

Currently, 50 battery storage systems are installed in the AllgäuNetz-area, further 30 are planned.

Follow-up plans

In view of the lacking grid-appropriate operation of battery storage systems there are considerations about area concepts. AÜW will take part in the EU-project ELSA (energy local storage advanced system), in this context area concepts for battery storage systems will be explored.

Transferability to other alpine regions

The transferability of the conclusions collected in the pilot project to other alpine regions is given, especially to rural areas with similar population structures and frame conditions.

Bavaria, Germany

Heat and Biogas storage in combination with combined heat and power and Power to Heat

Case study

Project Partners: Forschungsstelle für Energiewirtschaft e.V., München / Rothmoser GmbH & Co. KG, Grafing

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Case studies are contributing to AlpStore WP6

Work Package 6 Responsible: EUROIMPRESA LEGNANO s.c. a r.l.

Lead Partner: B.A.U.M. Consult, Ludwig Karg, Patrick Ansbacher, Anja Lehmann

1 Heat and Biogas storage in combination with Combined Heat and Power and Power to Heat for Grafing bei München - General frame conditions and objectives

The energy transition ("Energiewende") requires a large degree of flexibility in the energy network in Germany and Europe. As part of the **AlpStore** project, an analysis was carried out on the district of Ebersberg, especially in the city of Grafing, to allow an appropriate alignment of energy supply.

1.1 Actual and future regional energy system

With almost 132,000 inhabitants distributed in 21 municipalities, the district of Ebersberg is a medium-sized district located close to the Bavarian capital Munich. Since the suburban train was established in the 1970s, the district has become more and more attractive as a place to live and for recreation, resulting in steady increases in the number of inhabitants.

In 2012, the amount of locally generated electricity from renewable energies accounted for 102 GWh. Compared to the overall generated amount of electricity in the district, renewable energies provided a share of around 20 % of the total amount of power consumption. A look at the energy consumption in the district depicts that most of the electricity was consumed by the private sector (approximately 59 %), followed by the business sector with 36 %. Regarding heat consumption from residential buildings, calculations show that the amount of consumed energy has increased proportionally to the living space. This trend is likely to continue considering demographic projections.

Figure 1: The region of Ebersberg [Rothmoser]

The district of Ebersberg aims to reach a share of 100 % renewable energies in the region by the year 2030. The pioneering concept expresses not only the general interest in expanding renewable energy. It also determines specific target values for individual energy sources (photovoltaic, wind, biomass, etc.) and for the increase of energy efficiency.

The FfE calculated load profiles based on weather data, roof top potentials, characteristics of renewable power plants and some other sources (see FfE Regionenmodell) assuming the Ebersberg target values from 2030. Figure 2 shows the calculated power and load curves for week 20, 2030

(May). They are characterized by high energy production from photovoltaic (yellow and red) at noon. The red area corresponds to the excess of photovoltaic energy, which in these times cannot be consumed in the region itself. At these times the generation thereby exceeds consumption by almost a factor of four. At night, however, energy is still needed from conventional power plants or other regions (blue areas). This energy could technically also be supplied by storing excess energy.

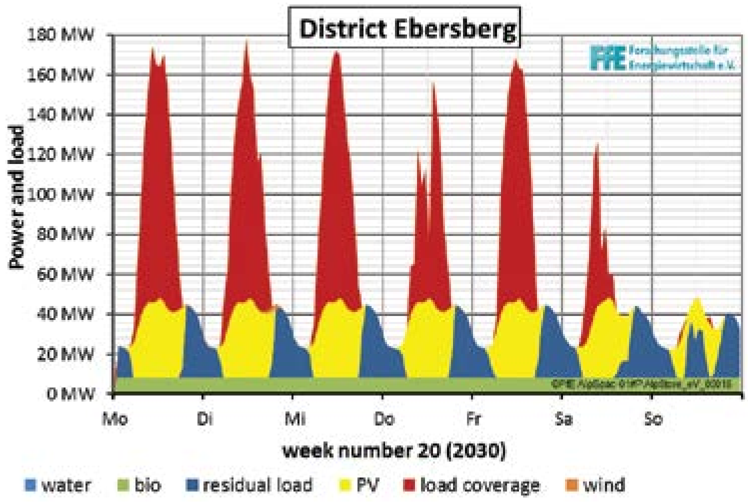

Figure 2: Estimated power and load curves for the region of Ebersberg by the year 2030 [FfE]

Due to the advantageous load coverage situation, energy storage systems are still playing a marginal role. The district currently has one underground gas storage plant in Wolfsberg. The plant is owned by RWE-DEA AG and entered into service in 1973. The 320 million cubic meter capacity gas storage plant is used by Bayerngas. Furthermore, there are 23 biogas plants that are mostly operated by Bayernwerk AG. With regard to electrical vehicles and battery storage systems, the district of Ebersberg is experiencing a rather slow development but future increases are expected.

A detailed simulation with load profiles according to the IKK shows the storage requirements for 2030. For this year, a non-dissipative seasonal storage of about 62 GWh could help the region become independent in terms of energy supply. A storage facility of this size is not viable.

62 GWh is approximately seven times the capacity of the biggest pump storage power plant in Germany. As there are no mountains in the region of Ebersberg, it is not possible to build such a huge storage plant. An alternative measure to reach this storage size would be the energy content of 6,200,000 m³ of gas (methane) or the storage capacity of around 2,400,000 electric vehicles.

A detailed overview on all storage options can be found in the master plan of energy storage systems Ebersberg, which was written as part of the **AlpStore** project.

1.2 Regulatory framework

In the district of Ebersberg, there is currently no specific support for individual storage technologies. On the other hand, no specific regulatory restrictions on the construction of heat and biogas storage facilities considered within the framework of the project are known.

Biogas plant in Grafing

Due to protests of some residents, the regional council did not allow an extension of the annual production of biogas in the biogas plant in Grafing. Therefore, a field test with biogas storage was not economically feasible within the **AlpStore** project. Nevertheless, this option has been regarded to as a simulation within the **AlpStore** project.

Heat storage

A survey which was conducted in Grafing (see Chapter 3.4) has shown that the construction of a heat storage facility in the urban area has a high acceptance rate. Based on this finding, a heat storage facility with an integrated Power2Heat (P2H) element is the focus of the case study Grafing in the project **AlpStore**.

What is Power2Heat? Why implement it?

The term "Power-to-Heat" or "Power2Heat" (short: PtH or P2H) refers to the transformation of electric energy to heat. Right now it is used mainly to provide balancing power. In future it could be used to integrate excess renewable energy into the system and therefor save fossil fuels for heating.

Legal regulations for P2H units

As there is only a small number of P2H units operating in Germany to date, information on legal issues is not so easy to find. For example, it is quite difficult to find the right contact persons within the involved public authorities such as the "Landesregulierungsbehörde in Bayern" and the "Bundesnetzagentur". Quite some time has been spent discussing and researching the legal issues for the following topics:

- **Connection-to-grid fee**

  The connection to grid fee is a one-off-fee and depends on the power demand of the P2H unit.

- **Network access fee (per kWh)**

  A network access fee has to be paid by all network users. Usually it consists of two components: the kilowatt-hour rate and the demand rate (kilowatt rate). Research has shown that P2H-Plants can apply for a reduced network access fee according to §19 Abs. 2 S. 1 StromNEV.

  This means that the demand rate does not have to be paid and it also leads to a reduction of the kilowatt-hour rate. However, the reduced network access fee is available only upon approval.

2 Pilot project Grafing

As part of the **AlpStore** project, a detailed study on biogas and centralised thermal energy storages in medium sized villages has been conducted in Grafing. Grafing bei München is a town located in Upper Bavaria, about 30 kilometers southeast of Munich. It is part of the district of Ebersberg and has around 13 000 inhabitants. The town is mostly rural with 83 % farm- and woodland.

Based on a survey of the inhabitants of Grafing, a simulation on optimal storage sizes as well as a test of a heat-storage facility with a P2H application was implemented in Grafing.

2.1 Characteristics of the field test

Why is Grafing a suitable place for a pilot implementation on a biogas storage and especially P2H in combination with heat stores? Based on a description of existing infrastructures in Grafing, this chapter describes the choice of Grafing for the pilot implementation and the examined storage options.

Choice of biogas and heat storages as future stores for the region of Ebersberg

In a first step, the whole region of Ebersberg was analysed. Many storage possibilities have been discussed and compared in the “Masterplan storages Ebersberg”.

The largest realistic storage potential in the region of Ebersberg can be seen in the field of thermal stores, more flexibility of combined heat and power (CHP) plants and in private households. Further storage possibilities are stationary batteries for PV-self-consumption and flexible biogas plants.

A detailed simulation with load profiles according to the IKK depicts a storage requirement of about 62 GWh in 2030, which is necessary to enable energy independency for the region. If one would hypothetically store the whole biogas production of the region Ebersberg during summer times in the existing public gas grid, the remaining need for storage for the region would be 33 GWh. Figure 3 compares different storage options for the region.

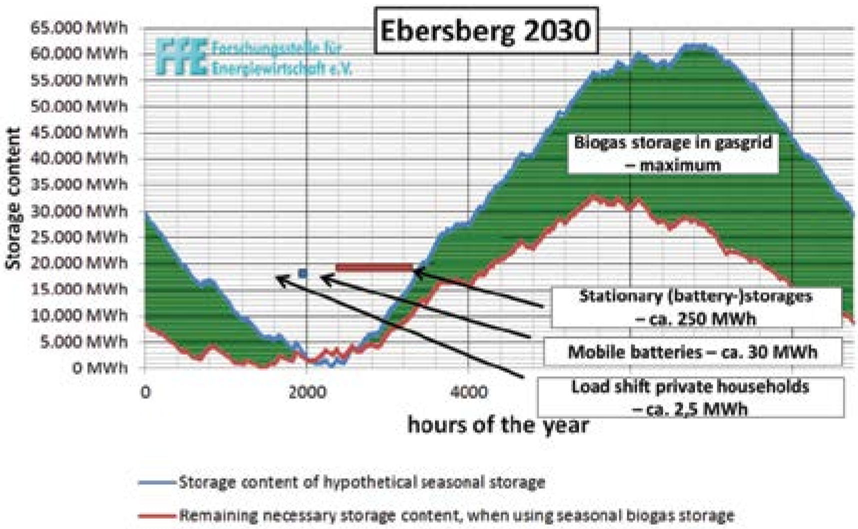

Figure 3: Possible impact of different storage options by 2030 [FfE]

To meet the future storage demand it could therefore be useful to investigate in biogas stores for a more flexible use in CHP and heat storage systems to integrate surplus renewable energy.

Biogas in Grafing

Since 2011, the local power supplier of Grafing, Rothmoser, uses biogas from a biogas plant (shown in figure 4) to operate CHP plants (cogeneration). The substrate, the biomass input to the plant, is composed of manure from local farms, plant remains and corn (grown by the biogas plant operator). Within ten days, the substrate releases biogas by fermentation. The fermentation residue can be used to fertilize the fields. There is a biogas pipeline between the biogas plant and the cogeneration plants, which are associated with two independent district heating networks.

Figure 4: Existing biogas plant close to Grafing. The existing small biogas storage is in the white building [Rothmoser]

District heating network in Grafing

There are two district heating networks in Grafing. The first is called “Gartenstraße” and the second “Am Stadion”, corresponding to the place where the heat is generated (see figure 5, left). The total length of the networks is about 4 km. They provide heat to the high schools, a primary school, a gymnasium, a retirement home, the HASI hotel as well as to residential complexes and private houses. Grafing is therefore an ideal pilot site to implement large scale thermal energy storages.

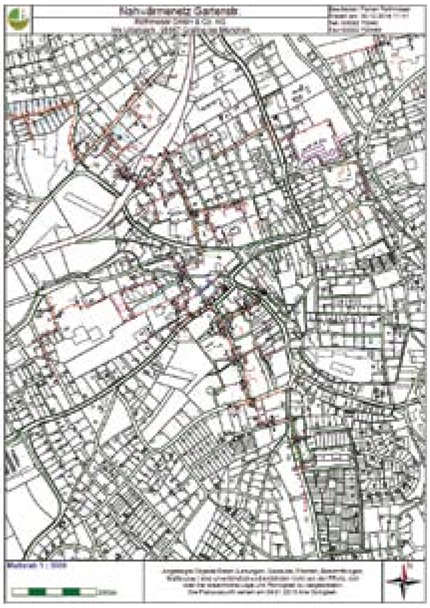

Figure 5: Schematic view of the two district heating grids in Grafing (left) and detailed view of the district heating grid “Gartenstraße” (right) [Rothmoser]

The smaller heating network (Am Stadion) provides heat mainly to public utilities like the outdoor swimming pool and the namesake stadium. The bigger one (Gartenstraße, 2) is located in the centre of the city, south of the first one (see figure 5, right).

Storage options in the field of heat and biogas in Grafing

The district heating network of Grafing is connected to several CHP plants. From a practical point of view this already existing infrastructure is a reasonable basis for a case study on storage possibilities in the alpine space. Several storage options are potentially feasible in Grafing:

A biogas storage could be installed in combination with an existing biogas plant close to Grafing, which is already operated by Rothmoser

Thermal energy storages are conceivable next to the different CHP in the centre of the district heating network

Electricity storage systems such as batteries are possible at any location in the electricity grid of Grafing.

Biogas potential in Germany

The total nominal power of existing base load biogas plants in Germany is currently about 3.3GW. If they were equipped with additional biogas stores, heat stores and a CHP plants with nominal electric power which is four times greater in capacity, they could provide about 13 GW of fully flexible power generation capacity. This has to be compared with the electricity demand which varies between 29 and 74 GW.

Choice of Grafing for pilot implementation in AlpStore

As illustrated in the master plan for the region of Ebersberg, heat and biogas storage systems are currently the most economically viable storage systems in the region of Ebersberg. Hence, a pilot implementation which demonstrates these storage systems can add the largest value to the region.

Meanwhile, many households are connected to the district heating grid in Grafing. Many people are therefore positively affected by the pilot implementation.

Did you know? The combination of biogas and CHP is typical for the region!

For some years, biogas and connected CHP plants have been typical for the region of Ebersberg. So far, these systems are not in tune with the electricity demand in the region. Therefore it is difficult to integrate fluctu-ating renewable energies like wind and photovoltaic systems into the energy grid. Heat and biogas storage systems can help to balance the production of the existing CHP plant.

As not all biogas potentials in the alpine space are developed so far, the findings of this pilot implementation in Grafing could be very interesting for other villages in the region with a lack of experience with these storage systems.

Design and objective of the case study

In the case study “Grafing”, the FfE considered the possibility of decoupling the power and heat generation in Grafing. Various benefits, such as an independent electricity supply for Grafing, an increased portion of produced renewable energy and decreasing energy prices could be obtained with such a decoupling.

To test the possibilities and chances in the field of heat stores, a heat storage with integrated P2H unit was set up in Grafing in collaboration with Glood GmbH, a local start-up company. The P2H unit can help to cut down consumption of natural gas during times of surplus electrical energy supply, as existing natural gas heaters can be stopped once the P2H unit delivers heat. Additionally, P2H can help to cover the heating needs in Grafing. Grafing's existing biogas CHP plant cannot provide the whole heat supply which is needed in the heating network with the current biogas production.

Why did the consortia choose to implement a heat and not biogas store?

Currently, the biogas plant is not driven at its full capacity, due to a legal requirement that only allows the plant to run at its present lower capacity. Grafing's administration needs to request permission for further biogas production. This permission has been denied so far, caused by the protest of some interest groups among the townspeople.

As it was therefore not clear if the legal restrictions that prevent investments in biogas storage will be changed in the future, heat storage with an integrated P2H unit was installed and investigated in Grafing. This new technology means converting surplus electrical energy, which is available at the control energy market, into heat.

The key visual in figure 6 illustrates the components of the case study in Grafing. The district heating grid can be fed with cheap heat from electricity (P2H). In the future, this electricity could mainly originate from renewable energy plants such as photovoltaic, wind and geothermal power plants. Furthermore the flexible heat production out of biomass is shown in the key visual.

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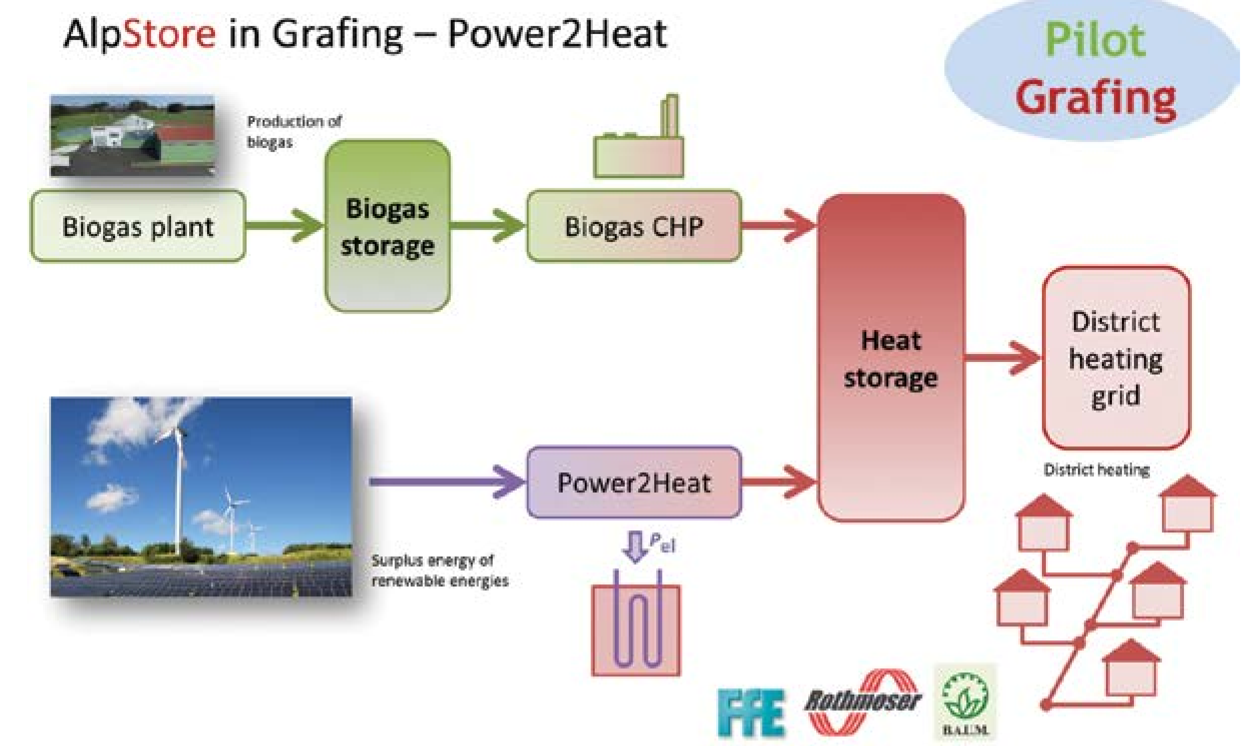

Figure 6: Key visual for the case study in Grafing [FfE]

2.2 Storage technologies and frame conditions

In this case study biogas and heat storage technologies are investigated. This chapter gives a short overview on these storage technologies.

Heat stores

Thermal energy storage (TES) systems are widely available and are used in every district heating network. TES allows the collection of excess thermal energy and storage for later use. The storage time can be hours, days or even weeks and months. There are many different TES technologies: heat can be stored in tanks, rock caverns, can include phase changes (molten salt technology) or can be based on solid materials such as concrete.

The most common TES systems are hot water storage tanks. Hot water storage tanks consist of a water tank that is heavily isolated. In district heating networks, stratified hot water storage tanks with closed water circuits are the state-of-the-art technology. The tanks are stratified with layers of water with different temperatures: the hot water is on top of the tank, while deeper layers are cooler.

Why is it beneficial to have different water temperature layers in a storage tank?

It can be explained with the example of a TES system which is not loaded to its full capacity, which is represented by a uniform maximum temperature of 85-95 °C. A half-loaded TES system with a uniform temperature distribution would have a temperature of around 45 °C. This water temperature level is not high enough to heat the district heat network. Instead of a half-loaded stratified hot water storage system, the system has a layer of hot water (around 85 °C) on top, with cooler layers of water ranging down to around 40 °C on the bot-tom, whereby water from the top can be fed into the district heating network.

In Germany, there is a sponsorship for heat and cold storage systems that contributes to up to 30% of the investment cost, with a limit of 2 million €. This is taken into account in the dotted line in figure 7, and can also apply for the construction of a storage tank in Grafing.

The price of water tanks depends a lot on the manufacturer and its size, but a summary of some tanks used principally in district heating networks is provided in figure 7.

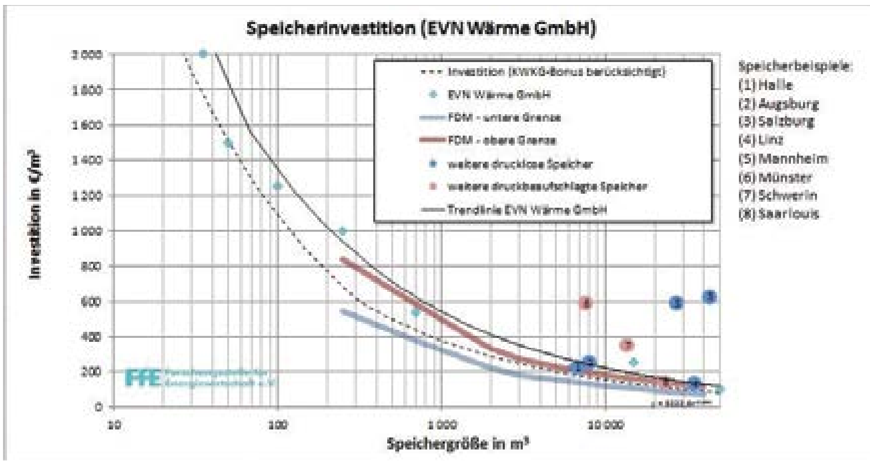

Figure 7: Investment costs for hot water storage tank [FfE]

The specific investment price for each cubic meter decreases with the total size as shown by the black line, and one can see that most of the district heating networks from greater cities have storage tanks with volumes of 6,000 m^3 to over 40,000 m3, marked with red and blue points.

There is available space in Grafing for a heat storage system next to the CHP-Hall at Gartenstraße (see figure 8). In the **AlpStore** project a heat storage tank with a size of 60 m³ was built here.

Figure 8: Space for a new, larger thermal energy storage tank at Gartenstraße in the center of Grafing [FfE]

The existing heat storage system as well as the connected CHP unit can be seen in Figure 9.

Figure 9: Existing thermal energy storage system in Grafing (left side) and CHP unit (right side) [FfE]

Biogas storage systems

One main finding of the master plan on energy storages in Ebersberg is that biogas has the biggest storage capacity in the region, as the construction of a pumped hydro storage is not possible. According to the integrated climate concept for the region of Ebersberg, there will be an installed biomass-capacity of 11 MW with an annual production of 75.5 MWh electrical power in the region by 2030.

Biogas is a form of chemical energy. It can be stored as any other gas, but cannot benefit from the existing infrastructure for natural gas as its percentage of methane is too low. Nevertheless, it can be stored in tanks.

A common size for biogas storage tanks is about 5,000 to 10,000 m3. Considering that the biogas plant in Grafing has an average biogas production of 340 m3/h and a maximum production of 450 m3/h, even a volume of 10,000 m^3 covers only 22 to 29 hours of production, which is far from providing seasonal storage for several months. Storing the biogas production of around 12 hours allows a flexible operation of the CHP units, which take night and day prices and energy demand into account.

Examples for current prices for 5000 m3 biogas storage tanks (different storage designs):

- 740,000 € for a metal construction
- 150,000 € for a flexible construction
- 80,000 € for a half fastened construction

2.3 Research design

In order to get an overview on all sides of the pilot implementation, the implementation team looked at the inhabitants of Grafing, the surrounding region Ebersberg, theoretical simulation based potentials and the practical implementation of heat storage systems in combination with P2H units.

Figure 10 gives an overview on the different steps of the pilot implementation in Grafing (Research design).

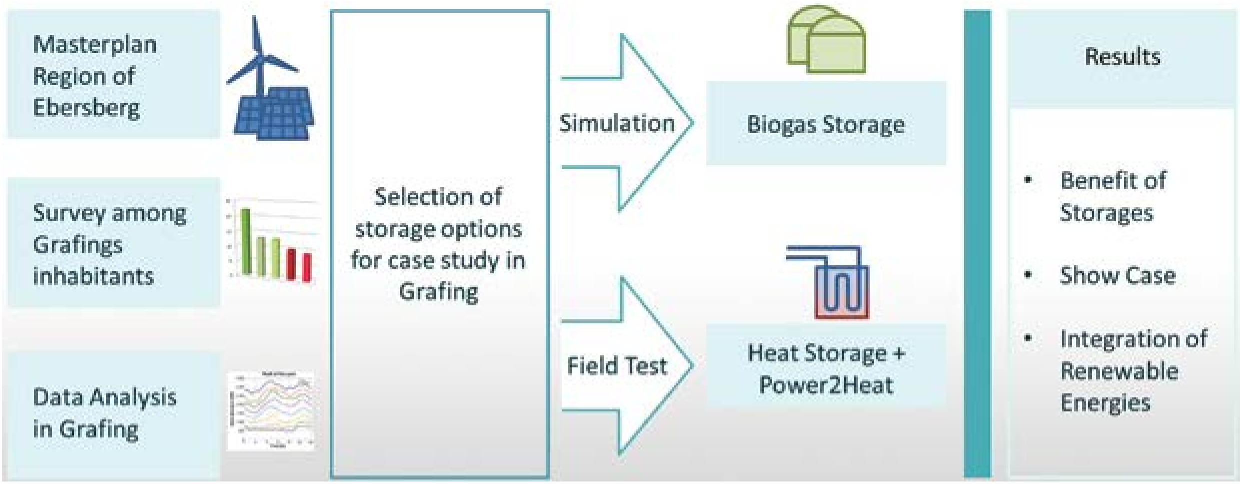

Figure 10: Overview of the different steps of the pilot implementation in Grafing [FfE]

Master plan energy storage systems for the region of Ebersberg

The “Master plan energy storage systems for the region of Ebersberg” summarizes all potential storage options, as well as the need for storage systems in the region of Ebersberg by the year 2030. It was written by the FfE and B.A.U.M. Consult as part of the **AlpStore** project and as a first step to identify suitable storage systems for a pilot implementation in the region of Ebersberg.

Survey among the citizens of Grafing

FfE and Rothmoser have conducted a survey among the citizens of Grafing addressing the energy turnaround and its local consequences. A possible increase in local energy production or implementation of energy storage systems could have an impact on the local community. Therefore, the public opinion on energy turnaround, energy storage systems and demand side management is an important factor. The survey has been conducted as an internet survey. Several measures have been taken to increase the number of participants, such as gift certificates for local businesses (10x20 €), several announcements in the Rothmoser Newsletter, the city council newsletter, the city council website (www.grafing.de), the Rothmoser website (www.rothmoser.de) and its Facebook account (www.facebook.com/rothmoser), as well as with flyers. 115 participants filled out the online survey.

Data Analysis in Grafing

An analysis of existing local power generation data (CHP, PV, water) and demand load curves aimed to identify storage potentials. Furthermore, it provides a basis for the accompanying simulations. The data source was mainly electric meter data from engines and heat meter data. The analysis has been partially undertaken within the Master’s thesis of Aurélie Babin titled ”Operation Optimisation of a District Heating System by means of the Integration of Energy Storages“ within the **AlpStore** project at the FfE.

Selection of storage options for the case study in Grafing

Based on these three analyses (Master plan, survey and data analysis), possible storage systems have been discussed (see Chapter 2.2). Biogas storage systems have been an option for the field test, but have been eliminated as an option (it will only be run as a simulation) for the following reasons:

- At the moment, the maximum allowed biogas amount per year is produced (2.3 million m³). However, the heating demand cannot be met by the biogas CHP plants alone. This means: maximizing profit by maximizing run time of the engines. An engine stop to store biogas would result in lower earnings, as long as the power is not sold at the exchange (EEX) and the operation is optimized with respect to the spot market price.
- The biogas storage would only make sense in conjunction with larger thermal energy storage where the power is sold at the EEX to benefit from high price situations. Further investigations would be necessary to determine if the investment would be profitable.
- Profitability is dependent on the total amount of biogas that is produced per year. As long as the total biogas amount per year is limited to 2.3 million m³, the expected investments do not appear profitable. An increase in the total biogas production per year up to the maximum capac-

ity of the biogas plant (around 3 million m³ per year) would justify further investments in biogas storages. The allowance for a higher total amount of biogas per year is dependent on the city council. The city council has not decided to increase the biogas limit so far, which could possibly change in the future. Since this is not certain, it seems reasonable to look at other possibilities for energy storage within the framework of the **AlpStore** Project.

Instead, heat storage with a P2H unit has been selected for the field test.

Simulation of Grafing's energy system with biogas storages

Detailed simulations on the future energy system in Grafing are being conducted by the FfE to see the impact of different storage options.

Field test of heat storage with integrated P2H unit

The field test of a heat storage system with integrated P2H unit can show the integration of surplus renewable electrical energy in the energy system.

Final Results

Based on the simulations as well as the field test of the heat storage with integrated P2H unit, results can be obtained in order to help future projects to design, build and operate their storages. The key questions are specifically: Which benefits can be expected of these storage systems? How does this kind of storage system work? Is it possible to integrate surplus renewable energy into the energy system by using these storage systems?

2.4 Implementation process of the P2H unit

The construction of the P2H Unit started on 9th of April 2014 after the thermal energy storage system had been delivered. The heat elements have been assembled on 5th of May 2014. Over the following months the hydraulic and electric integration of the P2H unit was completed. The control unit of the location "Gartenstraße" had to be expanded to integrate the P2H unit control.

First tests of the control unit have been conducted on 29.10.2014, with a final test on 13.11.2014. The goal of the tests was to ensure that communication based on GSM (Global System for Mobile Communications) between Trianel (group of energy suppliers) and the P2H unit is working.

Final approval of Trianel and the transmission network operator was given at the end of December 2014, so that Normal operation started on 22.12.2014.

Figure 11 shows the delivery of the new heat storage (left) and the installation of the P2H unit (right).

Figure 11: Delivery of thermal energy storage and assembly of heat elements [Rothmoser]

Figure 12 shows a scheme of the heat storage system with integrated P2H unit in Grafing.

The most important technical questions for the case study in the **AlpStore** project are:

- How many calls for operation take place (per day, per week)?
- How long is the typical call?
- How much heat is lost? What is the maximum storage time?

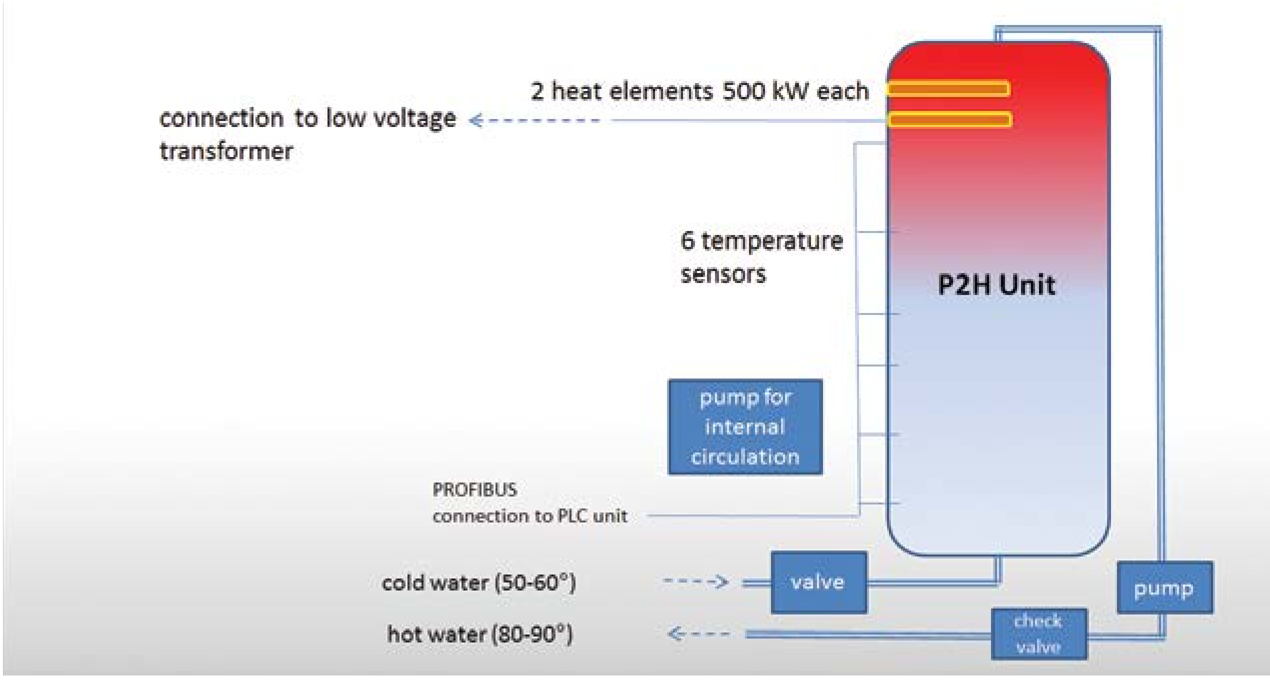

Figure 12: Scheme of the heat storage system with integrated P2H unit in Grafing [Rothmoser]

2.5 Simulations on biogas storages in Grafing

Supplementary to the pilot implementation, simulations on suitable storage sizes for heat, electrical and biomass storage systems have been conducted as part of the **AlpStore** project.

The results show the vital necessity of storage systems to ensure Grafing operates self-sufficiently. On the other hand, simulations show that from an economic perspective the need for storage systems is much smaller when taking the flattening effect of bigger regions with different kinds of renewable energies and different weather conditions into account.

The current biogas storage with a usable storage volume of about 1,600 m^3 (corresponding to a calorific value of about 8 MWh) could be filled within 3.5 hours at maximum biogas plant production. As long as the biogas plant is not allowed to produce at its full capacity over the whole year, this existing storage fits the daily need for flexible biogas production, even if an integration of the solar peaks is required.

Further simulations on suitable energy storage systems for Grafing can be found in the paper "Simulation of a Sustainable Energy System in Grafing" which was published by Stefan Bschorer and Florian Samweber on the international solar integration workshop in Berlin.

3 Main outcomes and benefits of the Pilot implementation

All examinations in context of the case study in Grafing give insights into the future possibilities of heat and biogas storage systems. This chapter gives a short insight into technical findings, economic effects, environmental impacts and social benefits of the implemented heat storage with integrated P2H unit.

3.1 Technical Findings

The P2H unit started its operation in late December 2014. As of 07.01.2015 six calls took place. The maximum power per call varied between 50 and 800 kW. All calls occurred during the early morning, the duration time varied between 2 and 10 minutes. Table 1 gives an overview on the calls.

Table 1: Overview on operation characteristics of the P2H unit

Date	Time	max. power [kW]	duration [minutes]
29.12.2014	08:00	300	2
31.12.2014	08:00	120	2
02.01.2015	05:00	250	3
05.01.2015	04:00	50	2
05.01.2015	05:20	800	10
05.01.2015	06:05	300	8

Therefore the short calls with low power cannot be used to feed heat into the district heating grid, as the maximum temperature is below 80 °C (compare figure 13). This is illustrated by the example of

02.01.2015, when a short call at 5.00 a.m. led to an increase of the maximum temperature to 70 °C. In this case, the maximum temperature sank down to 60 °C within a period of one hour, probably because of instable layering or a too-small amount of heated water.

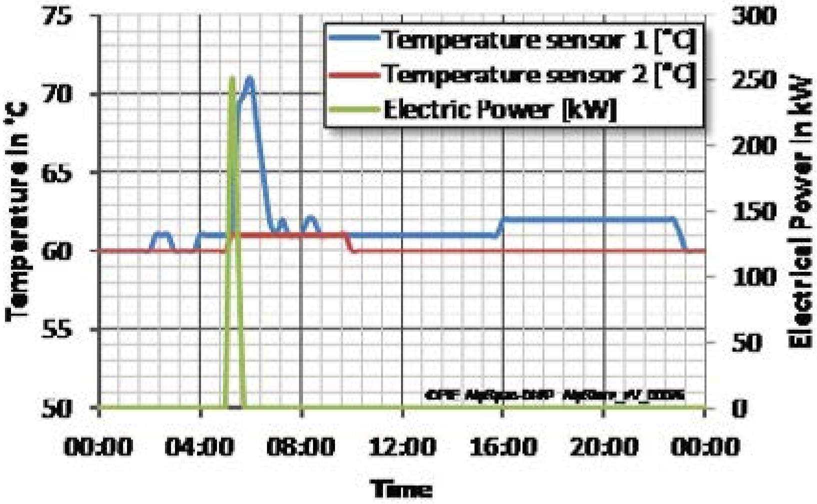

Figure 13: Example for short period call of the P2H device [FfE and Rothmoser]

On 05.01.2015, three calls (each of several minutes duration) occurred. Only after the third call the temperature within the heat storage reached 80 °C (compare figure 14). When the temperature at sensor T1 reaches 81 °C the pump starts to feed the heat into the district heating network. This fits to the purpose of the regulation, which is to pump all of the water that has sufficient temperature (≈80 °C) to the customers. On January 5th the pump stopped once temperature T1 fell below 76 °C. The pumping duration seemed to be too long in this case as temperature fell below 76 °C (down to 63 °C).

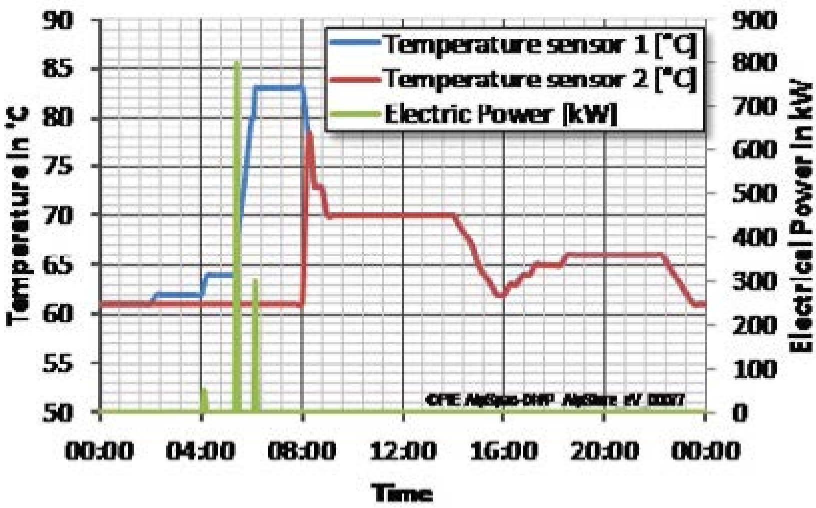

Figure 14: Example for long period call of the P2H device [FfE and Rothmoser]

The amount of heat (measured in MWh) delivered into the grid should not be higher than the accumulated electric energy during the call, as this indicates that water with lower temperature is being pumped into the grid.

Potential to improve the system

There is a small amount of water that is constantly draining from the P2H unit into the grid, as the check valve is open to the grid side. An average heat spill of 16 kWh per day was measured, which seems to be an acceptable value, as this is only a fraction of the estimated heat supply. Should further investigation lead to the conclusion that the heat spill is too high, one solution could be to fit the existing valve at the entry with servo motors that close the valve as long as the pump is not operating. However, taking into account the significant costs for additional hardware and programming, it is favourable to avoid installing the automatic valve.

Did you know? The circulation pump within the heat storage

The circulation pump enables continuous heating of the whole storage system. The circulation pump starts if the temperature at the upmost temperature sensor reaches the start value and stops if a second temperature value is undercut. At the moment the start temperature is set to 88 °C, the stop temperature is set to 85 °C. Whether these temperature values enable optimal operation or need to be changed is the subject of further investigation.

Technical key findings:

Operating on the control power market, the P2H unit ran only for short periods during the project **AlpStore**.

There are several minutes with high power necessary to heat the water to a temperature of 80 °C which is necessary to use the heat directly in the district heating network.

It is important to ensure a good temperature layering within the heat storage.

3.2 Economic effects

To give an insight into the economics of the P2H unit, this chapter provides a short overview on investment costs, costs of operation (Network acess fee, taxes and allocations) as well as the benefits of P2H.

Investment

Investment costs include costs for the heat storage, transport and lifting of heat storage, heat elements and heat element installation, electric installation and control and programming. The investment from Rothmoser was around 70,000 €, while the investment of Glood GmbH (which includes heat elements, GSM communication unit and electric installation) is in the dimension of 10,000 €.

Network access fee

P2H units can apply for a reduced network access fee. This means that the demand rate does not have to be paid, and a reduced kilowatt-hour rate is charged.

Taxes and allocations

Consumption of electrical energy is taxed by the Government in several ways, which also applies to P2H units:

- EEG-Umlage (renewable energy allocation),
- KWKG-Umlage (combined heat-and-power allocation),
- Konzessionsabgabe (concession tax),
- Stromsteuer (electricity tax),
- Offshore-Haftungsumlage nach § 17 EnWG (offshore liability allocation)
- Umlage für abschaltbare Lasten nach §18 AbLaV (load allocation which can be switched on and off)
- § 19 Abs. 2 StromNEV (reduced grid usage cost allocation)

Benefits of P2H

On the one hand a P2H unit can reduce the need of conventional gas, as heat from natural gas is replaced by heat out of renewable electricity. On the other hand, the P2H unit obtains a compensation for its participation at the control market. There are weekly auctions, where kilowatt-hour-rate and standby compensations are determined. Low kilowatt-hour offers lead to more calls per week and vice versa. In the first week of operation (22.12.2014 - 29.12.2014) a price of 500 €/MWh was offered at the control market auction, which led to only one call with a duration of two minutes. A lower price per MWh would result in more calls per week.

3.3 Environmental impact

The P2H unit is built on an already concreted area, so no additional surface sealing was required for the pilot implementation.

There are no local emissions caused by the P2H unit. In fact, CO_2 emissions are avoided when heat from the P2H-Plant is used for community heating.

The heat for the community heating grid is generated by the following sources:

- Natural gas heating
- Combined heat and power plants running on natural gas
- Combined heat and power plants running on locally produced biogas
- Combined heat and power plants running on biomethane

Every MWh of heat generated by the P2H unit replaces heat that otherwise has to be produced by natural gas heating, as the CHP plants are not stopped when the P2H unit delivers heat.

One Kilowatt-hour of heat from natural gas heating results in 200 g of C02 emissions. A conversion rate of 90 % was estimated for converting electrical energy into heat, taking into account heat losses and the efficiency rate of the heat elements. An annual CO_2-reduction of 1 to 18 tonnes can be achieved, depending on the operating time, as illustrated by the table 2.

Table 2: Avoided CO_2-Emissions in dependence of runtime

operating time [h]	Energy consumption [kWh]	generated heat [MWh]	avoided CO_2-emission [t]
50	10 000	9	1,8
100	20 000	18	3,6
250	50 000	45	9
500	100 000	90	18

3.4 Social benefits

Renewable energy technologies have quickly developed during the last years. Many citizens are not fully aware of the advantages and disadvantages of the required new technologies. The aim of a preliminary survey with 115 participants was to include the needs of the local citizens into the planning of the case study. Taking the results of the survey into account, the implementation team was able to design a pilot implementation which was socially accepted in the city of Grafing. Several questions were raised in the direction of the existing biogas plant (an important research focus of this case study). One key result was that opponents of the biogas plant mostly thought that the energy transition was premature; even if some of them considered the existing biogas plant to be good or rather good (see Figure 15).

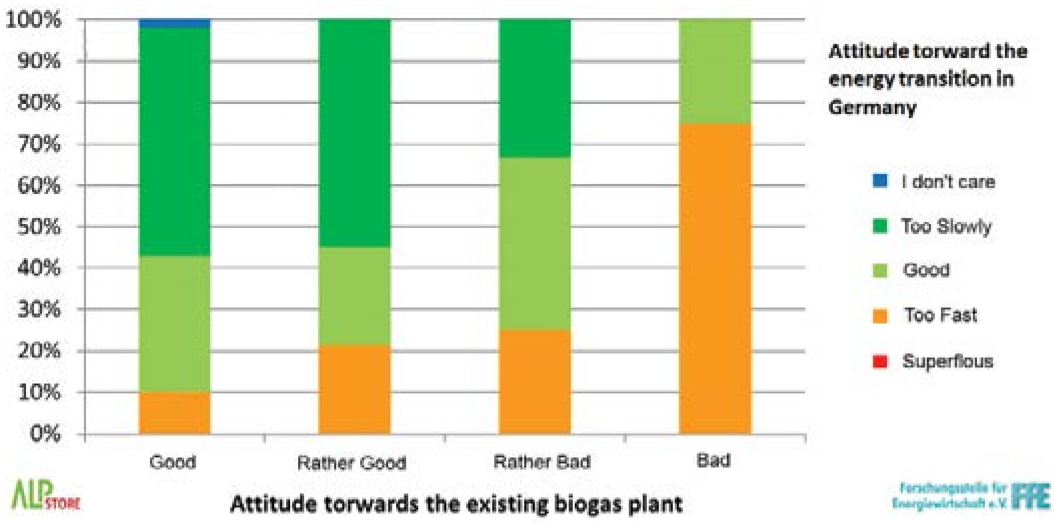

Figure 15: Attitude towards the energy transition in Germany and the biogas plant in Grafing [FfE]

One question of the Grafing survey aimed to identify the main arguments for a storage system in the municipal area. Besides support for local energy production, the reduction of CO_2 emissions and a decline in nuclear power in the electricity mix were the most named options. Figure 16 gives an overview on all answers. In the "other" category, very few people mentioned that the locals would benefit from the energy transition and the locally produced energy, but most of them thought that only the local energy provider would benefit. This question shows that people do know in general that a storage unit has benefits.

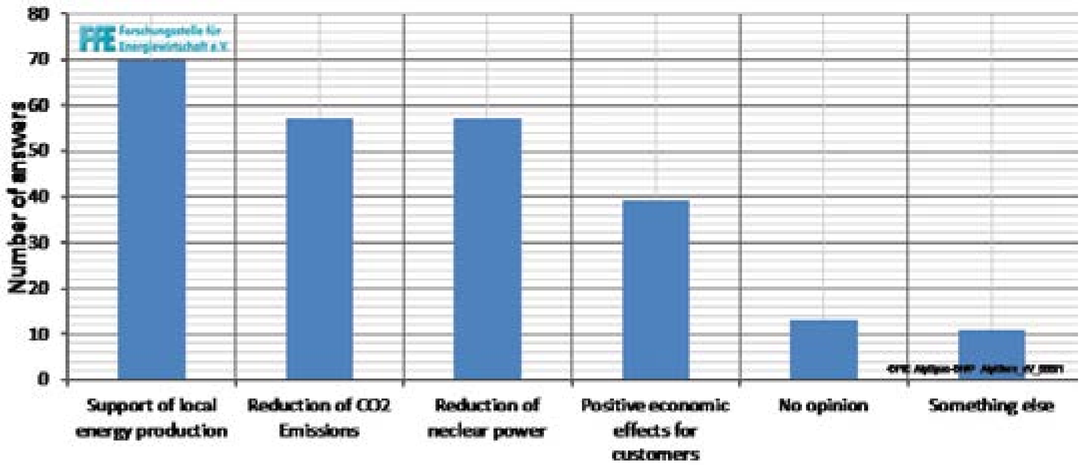

Figure 16: 11 Answers to the question: "What are your main arguments for a municipal storage system?" [FfE]

To design the storage system according to the needs of Grafing's citizens, one question investigated the criteria such a storage system should fulfil. The most important criteria was a small interference with nature and landscape, as well as a high ecological sustainability and an independent energy supply for the city. The place and size of the storage was not that important (see figure 17).

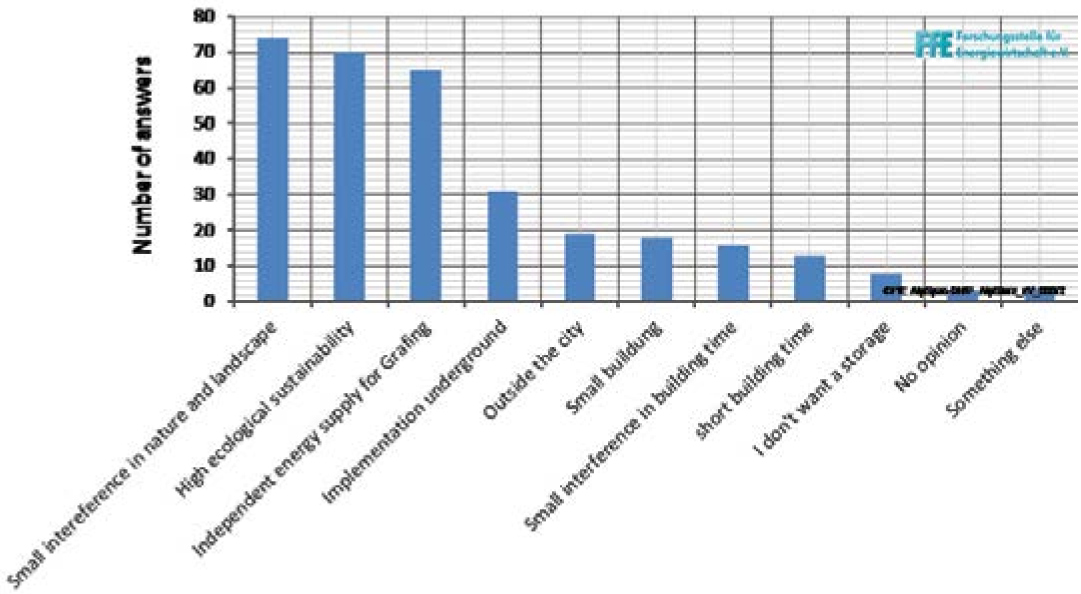

Figure 17: In your opinion, what criteria for a municipal storage are important?

All in all, the analysis of the survey results has shown an approval for the energy transition and a readiness to support the main themes of local and renewable energy, both by acting and in finance.

4 Conclusions

This chapter gives a short overview on the regional potential of the investigated stores, follow up plans and the transferability to other alpine regions.

4.1 Regional potential of the tested local options

Simulations carried out with the case study in Grafing showed how the biogas production can be adapted to the fluctuations of other renewable energy sources such as photovoltaics. Figure 18 depicts a reduction of the surplus coverage (red area) as well as a reduction of the maximum residual load compared to the inflexible load curves (compare with figure 2 in Chapter 1). This simulation implies that making the biogas plants flexible does not completely solve the problem of fluctuating energy production of wind and photovoltaic power plants. However, it will contribute to a future energy system in the region of Ebersberg with a huge amount of renewable energies. Furthermore, it is important to run flexible biogas plants depending on the production of the other renewables and not on the EPEX-prices in order to relieve the regional electricity grids.

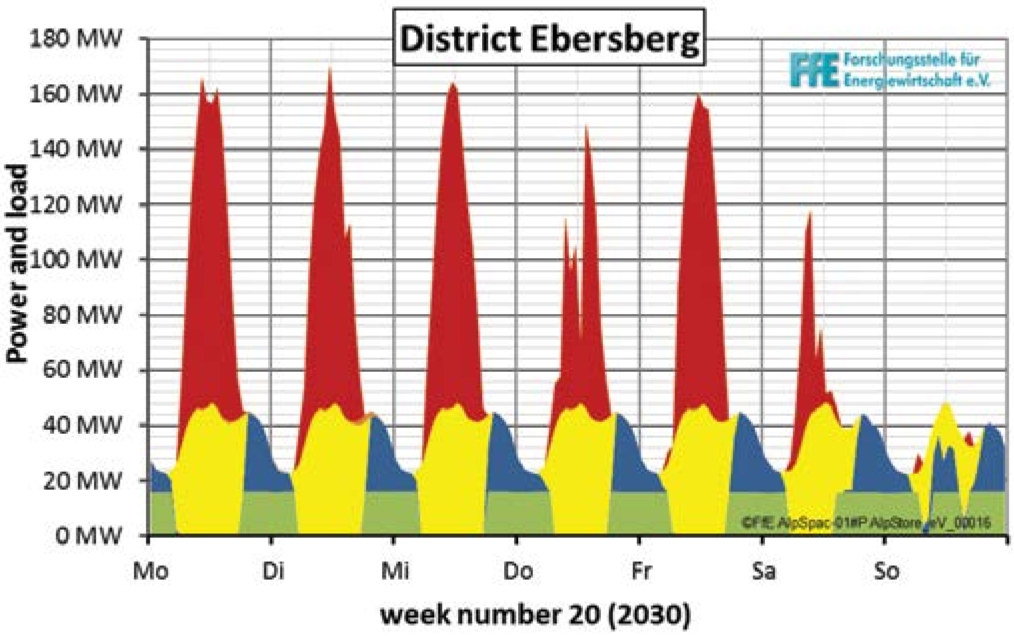

Figure 18: Power and load without biogas flexibility and with biogas flexibility [FfE]

In principle, the P2H unit could also be built next to each heat consumer in the region to integrate surplus renewable energies in future. Therefor the existing potential for P2H is almost limitless in the region of Ebersberg. To get a useful installed capacity one should take the capacities of the electric grid as well as the needed amount of heat into account.

4.2 Follow-up plans

Following the case study in the project **AlpStore** leads to different possible next steps. Beside an electric power scale up and a normal operation there are options for further research.

Electric power scale-up

Once economic feasibility of the P2H unit is proven and no technical problems in daily operation arise, additional heat elements could be installed. There are three additional flanges for heat elements which are not used at the moment. Electric power could be increased to a total power of 2.5 MW in the implemented heat storage.

Participation at the control energy market with biogas CHP-plants

Demand and supply of electric energy always has to be in balance. This balance is guaranteed by the control market. Power plants which have some flexibility can make offers at the control market, which is organized as a weekly auction.

Due to decreasing compensations for electricity generated from biogas and increasing prices for energy crops, more and more biogas plants will participate in the control energy market. This is only possible if the biogas plant has a biogas storage system and a bigger heat storage capacity is available.

Decoupling of heat and energy supply is a prerequisite for participation at the control market, but it has to be determined if the necessary investments for storage would be justified by the higher gains. P2H could be coupled with generation of electricity, so positive and negative control energy could be provided.

As mentioned, biogas storage would be a very interesting and promising solution for the biogas plant in Grafing and other biogas plants. Due to decreasing compensations for electricity generated from biogas and increasing prices for energy crops, more and more biogas plants will participate in the control energy market. This is only possible if the biogas plant has a biogas storage system and a bigger heat storage capacity.

Further research

The scientific part of this case study could be thought further as well. In a future energy system with a high share of renewable energies more storage options could become necessary. In order to choose sustainable storage options the long-time effects on the environment, the society and the electric grid should be taken into account in the future.

4.3 Transferability to other Alpine regions

P2H as it was implemented in Grafing is applicable in any region where community heating is available, while biogas is available in regions with an existing biogas plant. It would be the subject of further investigation how the control market is organized in other countries and if legislation and technical organization allow the use of P2H systems or not.

Lombardy, Italy
Energy in motion
Case study

Project partner: A.L.O.T. s.c.a r.l. Agency of East Lombardy for Transport and Logistics
Authors: Ilaria Leonardi, Enrico Peruchetti, Guido Piccoli (ALOT S.c.ar.l.)
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Case studies are contributing to AlpStore WP6
Work Package 6 Responsible: EUROIMPRESA LEGNANO s.c.ar.l.
Lead Partner: B.A.U.M. Consult, Ludwig Karg, Patrick Ansbacher, Anja Lehmann

1 Energy in motion

The goal of ALOT pilot project is to study and demonstrate that the relationship between the production of energy from renewable sources and the storage systems in the Province of Brescia are to be considered in the choice of location of charging infrastructure for electric mobility of the whole province. This study also aims to localize and create a map of the charging points station in relation to the combined production and storage plants in the Province of Brescia. ALOT pilot project is focused on the analysis of storage applied to the production of renewable energies in support to electric mobility; therefore it is different, but might result complementary, from other AlpStore pilot projects that focus on a specific technology.

1.1 Regulatory framework from European to national and local level

There is not a clear and defined regulation on a local, national and international level about the charging station network and electric mobility. Nevertheless the pilot analyzed the most recent directive from the "European Commission on the development of infrastructure for the distribution of alternative fuels" PE-CONS 79/14 (hereinafter AFID) and the "National Plan of infrastructure for charging the vehicles powered by electricity" (hereinafter PNIRE).

European Directive on the development of infrastructure for the distribution of alternative fuels

The European Directive on the implementation of an infrastructure for alternative fuels has been recently approved as a reference document to which the PNIRE will have to adapt. The main topics of the document pertaining to electric mobility are summarized in the following points:

- Charging points are distinguished only as "SLOW" (capacity of less than 22kW) or "FAST" (power of more than 22kW).
- Stands out as time horizon for planning the implementation of the network the year 2020.
- There is no reference to the number of charging stations that should be implemented by each state, leaving free the national governments to quantify the size of the network.
- Provides for the adoption of specific measures to support the spread of electric mobility, with particular reference to: direct incentives for the purchase of vehicles powered by alternative fuels or for the construction of infrastructure; possibility of tax incentives to promote public transport powered by alternative fuels and infrastructure; use of public procurement in support of alternative fuels, including joint procurement; non-financial incentives on the demand side: e.g., preferential access to restricted access areas, parking policy, dedicated lanes, ...
- In a first version, the directive provided to Italy a number of public charging points equal to 1'255'000, which, if they were scaled on the basis of the population would result in 25.000 charging points for the Province of Brescia, of which 2.500 public.

National Plan infrastructure for charging vehicles powered by electricity

The Ministry of Infrastructure and Transport, also in response to the EU guidelines on the need to adopt a policy for the distribution of vehicles powered by non-conventional power supply, has developed a plan that aims to facilitate and guide the development of the recharging infrastructure. First of all, it is important to note that the PNIRE is designed as a living document, which will be updated on an annual basis. This, while it ensures an optimal implementation of new technologies and rapid adaptation to any Community provisions, on the other hand is also a potential element of instability, which can drive away investors who fear a change in the policies for the infrastructure, which would affect re-entry of any investments and business initiatives in the sector.

From the document, recently approved, in accordance with paragraph 1 of Art. 17 septies of Law no. 134 of 7 August 2012, it is already possible to draw some important information:

- The PNIRE provides, among others, the installation of 90.000 publicly accessible re-charging points within the 2016, 110.000 within 2018 and 130.000 within 2020. The implementation of the plan will be realized thanks to specific "program agreements" that should be approved by the CIPE (Interministerial Committee for Economic Planning) and by the Decree of the President of the Council of Ministers;
- All electric vehicles must be able to count on two "private" charging points, as well as on a number of public charging points ("supplementary charge") to avoid the anxiety of running out of fuel;
- Consumers must be able to sign contracts for the supply of electricity simultaneously with several suppliers;
- The management of publicly accessible charging point should be possible for any business owner, in which energy suppliers must work together on a non-discriminatory basis;
- three charging modes are identified: SLOW (up to 3.7kW), QUICK (up to 22kW), FAST (over 22kW);
- as a ratio of 1:8 for public charging points compared to private charging points is defined;
- It outlines the parameters on which to base the planning of the implementation of the charging network: population, density, area, motorization rate, average age of the vehicle fleet, emission levels of CO_2 in the affected area.
- the activation of a "Unique National Platform" (PUN) that will serve for the monitoring and management of charging stations. Currently, the platform is not active;
- In order to integrate electric mobility in the context of Mobility and Logistics Plan at the local level (the Urban Transport and Urban Mobility Plan) and at the regional level (Regional Transport Plan and Logistics) it is necessary to create an electric plan of mobility within the mentioned Sector plans;
- the PNIRE encourages the implementation of integrated programs for the promotion of technological adaptation of existing buildings, with particular reference to the simplification in construction law and the charging points and the requirements of urban planning. In addition, the Plan requires to the Regions to establish methods, deadlines and content in the zoning laws, in order to permit to the municipal and supra-municipal planning instruments to be adequate with the provision of a minimum standard of facilities, both public and collective, of charging points for electric vehicles. It is also necessary to specify that at the end of 2014 the Lombardy Region Council approved a law that promotes alternative fuels and it previews, among others, the installation of charging stations in new or in restructuring service stations.

2 Pilot project

Purpose of the pilot and technology chosen

The development of E-Mobility is supported on a local, national and international level, by various converging elements: the use of renewable energy for mobility, the reduction of pollution in urban area, the optimal exploitation of the renewable resources (discontinued and distributed over the territory). These issues at the moment are perceived with difficulty both on the political/regulatory level as well as on the technological level, perceived as coming to create a sort of "vicious circle": as it can be seen when comparing the conclusions obtained in the different documents that deal with the potentiality of penetration of the electrical mobility[1], **it is too risky to invest on new technologies in absence of clear indications on the political plan, but it is also difficult to regulate a technological system that is still very little defined.**

The pilot "Energy in motion" aims to break this vicious circle, providing a sustainable regulatory proposal, which can be exploited both politically and on the technological plan. In particular, the pilot is an analysis of the territory of the Province of Brescia, aimed at defining an optimal architecture for a network of charging stations for EV, which is at the same time an infrastructure for the storage of electric energy produced by renewable resources. The pilot provides both technological indications and business model for companies and stakeholders that will manage the charging/storage stations (service providers).

As regards the component "storage" the pilot is based on the following points:

1. Lombardy is the first Italian region and **Brescia is the first Italian Province for installed power of renewable energy**[2];
2. the well-known **problems relating to the presence of a strong component of uncontrollable and unpredictable generation such as distributed generation from renewable sources in an electrical grid**[3]: for these reasons Brescia is an ideal "test-bed" for innovative solutions;
3. statistics that indicate that **a car is parked for an average 95% of the time**[4]: this situation shows how, in an EV, the battery can conveniently be used to perform storage functions on the electricity grid or, on the other side, how charging station could conveniently optimize their impact on the grid, adopting storage systems.

As regards the component "electric mobility", the pilot is based on:

1. **past experience**, which showed a limited penetration of electric mobility in the Province of Brescia, especially in comparison with the encouraging results achieved in other contexts;
2. **environmental needs** to reduce air pollution at local level, since the urban area of Brescia is one of the most polluted in Europe, mainly due to the great incidence of road transport in the mobility and logistics[5];

[1] Such affirmation is derived from the following documents:
- Smart Energy Report 2013 – Energy and Strategy Group – Politecnico di Milano;
- "Piano nazionale infrastrutturale per la ricarica dei veicoli alimentati ad energia elettrica" – Ministry of Infrastructure and Transport;
- Planning of EV charging infrastructure (a toolkit) – Community Energy Association – British Columbia

[2] "Statistical Report 2012 - Plants in renewable sources - Electrical Sector ", GSE S.p.A

[3] "Possible innovative modes of supply of resources for dispatching services from non programmable renewable sources and distributed generation " – Politecnico di Milano Report for A.E.E.G. (Prof. M. Delfanti, Eng. V. Olivieri) – June, 2013.

[4] "Individual and public Electromobility, pre-normative research on a European and Transatlantic level", Dr.-Eng. Harald W. Scholz, Dr. Elena Paffumi, Dr. Michele De Gennaro - CCR di Ispra (VA) - Joint Research Centre Institute for Energy and Transport (IET)

[5] "Air quality report in the Province of Brescia in 2012", ARPA Lombardia.

3. **the existence of a strong SMEs network** that are at the same time potential users of the service (e.g. corporate fleets), and potential suppliers of technological solutions related to the creation of the network of charging/storage stations.

2.1 Locations for the pilot

Demographics

The Province of Brescia is an Italian Province counting 1'259'189 inhabitants[6], second Province in Lombardy according to the number of inhabitants. It is also the largest Province of Lombardy, with an area of 4'784.36 km² and a population density of 264 inhabitants per km². It includes 206 municipalities.

Transportation and mobility

The Province is crossed from West to East by the A4 highway that intersects near the capital the A21 from the South. Due to the local geography, the roads run from the capital to the outskirts of the Province (lakes, valleys, plains) in a radial pattern. The Province records a per capita rate of car aligned to national average (607 cars/1'000 inhabitants, national average 625 cars/1'000 inhabitants[7]), constantly and steadily increasing in recent years. This situation leads to problems related to air quality, especially in the vicinity of the capital, center of the provincial road network.

Energy grid, distributed generation and storage

The Province of Brescia today maintains its historical vocation to exploit local and distributed renewable energy, through: the reactivation of small-scale hydropower plants (this activities will reach its climax in the years up to 2015, also due to an important incentives[8]); and the construction of numerous photovoltaic systems that make it the first Province in Italy for number of installed plants of this type.

The territory is characterized by an important network of power lines in high and extra-high voltage which ensures an optimal interconnection with transalpine networks and with national network. Recently the area has been characterized by a great development of "distributed generation"[9] and, within this, of the "small generation"[10] and of the "micro-generation"[11]. In this area between 2007 and 2011 there was a peak of photovoltaic installations, which brought the Province in the first place in Italy for number of installed plants[12]. The presence of a strong component of electric generation not controllable and unpredictable, such as distributed generation from renewable sources, involves issues related to the adjustment of the network parameters (especially frequency and voltage) and to the optimal utilization of the energy produced. This could be faced adopting smart storage technologies. Energy storage as close as possible to the unpredictable production is recommended. For this reason Brescia is an excellent test-bed for storage solutions, as well as to the reconfiguring of the electricity network, which must abandon the obsolete "star" architecture to take on a "grid" architecture. This search field concerns the so-called "smart grid": intelligent power distribution networks, capable of routing and/or storing any surplus of energy, thus maximizing production efficiency and

[6] Data ISTAT 2012
[7] Data Automobile Club Italia @ 2011, December 11th
[8] DM 6 luglio 2012 "per la promozione dello sviluppo di FER non fotovoltaiche"
[9] Plants with nominal power lower than 10MVA
[10] Plants with nominal power lower than 1MW
[11] Plants with nominal power lower than 50 kW
[12] AEEG "Monitoraggio Generazione Distribuita" - 2011

avoiding waste.

Automotive

The Province of Brescia has developed an early industrialization in the late 1800's and early 1900's, seeing the emergence and rapid expansion of many important companies specialized in mechanical processing of metals. This manufacturing vocation is justified by the local presence of the previously mentioned energy resources, alongside relevant mining reserves (mainly iron), to date nearly completely exhausted. Brescia is nowadays the first automotive district in Italy. This vocation is confirmed also by the six manufactures of cars which arose in Brescia in the early twentieth century.

2.1.1 Involvement of Regional Stakeholders

A2A SpA

A2A SpA is one of the major electricity suppliers in the Province and nationwide. A2A gave its support on technical aspects and for the collection of economic and financial parameters to process the business model as a charging service provider. In 2010, A2A developed “E-moving” pilot project during which it installed 18 charging points in Brescia and 30 in Milan. While in Milan the installation of recharging points was well accepted by users and rewarded with significant numbers of recharges, in Brescia it was mainly ignored because users do not need to move only within the area covered by the charging network. The experience gained will allow A2A to solve problems that have rendered non-functional the project “*E-moving*” in Brescia, optimizing the use of the infrastructure previously created.

Lombardy Region

Lombardy Region, also according to the reform of title V of the Constitution, is an institution that has a specific power to standardize and regulate electric mobility and power generation. The collaboration with this institution allowed the full development of the pilot's regulatory aspects, analyzing the critical elements that can slow the spread of recharging/storage infrastructure and developing a shared template that can be quickly and effectively implemented in other Provinces in Lombardy and also in other Regions.

Province of Brescia

The Province of Brescia collects and analyzes statistical data about geographic, social, economic, demographic and mobility indicators. Those data were at the base of the definition of the recharging/storage stations infrastructure within the pilot project. The collaboration with this institution is therefore fundamental to establish pilot results on solid statistical bases, minimizing as much as possible errors in the assessment of the potential demand of the charge service.

Mobility Manager

In order to complete the data obtained from the Province, the support of “Mobility Manager”(MM) was asked for. These figures, introduced by the Decree of the Ministry of the Environment on 27 March 2008, should be mandatorily appointed by public or private companies with more than 300 employees at a single location or from companies with over 800 employees across multiple locations improvement of commuting. Their objective, working within the bodies/companies belonging to them can be summarized in the following points: reduction of the vehicle traffic, energy saving, reduction of the polluting emissions, reduction of green house gases, reduction of traffic congestion phenomenon, increase in safety on the roads.

Other partners

During the development of the pilot, the collaborations with other partners that were enabled both for technological aspects and for the development of the business models were very important. In particular, technological partners were companies active in the production and distribution of charging/storage systems and EV, as well as companies in the automotive sector.

2.2 Research design and schedule

2.2.1 Planned Activities

The process that guides to the definition of the charging network architecture is divided into three main phases:

1. Defining a map of optimal locations for storage/charging stations and developing a business model to identify economically sustainable management mode for the infrastructure;
2. Definition of a regulatory framework and a planning communication program that encourage and promote the dissemination of charging points and storage, in particular during the first penetration of electric vehicles in the Province;
3. Definition and description of the methodology adopted.

The following table lists the Planned Activities for the pilot.

	PA	Description
PHASE 1	0	Information gathering
	1	Data gathering concerning renewable energy plants, storage opportunity and e-mobility trends
	2	Estimation of the demand for electric mobility and therefore of potential charging infrastructure for different roads
	3	Estimation of demand for storage for the electrical network in the different meanings of frequency, voltage control, and fault recovery
	4	Development of network map of stations (definition of "locations")
	5	Identification and analysis of the technical requirements of the charging/storage station, economic assessment at local and provincial level
	6	Business model definition
PHASE 2	7	Definition of legal/regulatory setting (proposal for Lombardy Region)
	8	Planning a communication program
PHASE 3	9	Definition and the description of the Methodology adopted.

2.2.2 Lesson learnt: definition and description of the innovative Methodology adopted

1. **Activating the stakeholders**
   - Contacts with the public administration to observe specific exigencies and criticality
   - Contacts with the grid operators
   - Definition of the objectives
2. **Acquire the knowledge of the Territory**
   - Acquisition of information with regards to existing pilot projects
   - Acquisition of salient information with regards to the territory division (demographic indicators, vehicular park)
   - Definition of the technical specification of the network (which vehicles? What extension? What type of stations?)
   - Definition of the criterion of localization of the stations depending on the prefixed objectives.
3. **Data Collection**
   - List of the relevant roadways in order to localize the stations
   - List of renewable energy plants in Province of Brescia
   - List of points of interest/attracting poles of traffic relevant in terms of localization of the stations.
   - Collection of data in a numerical way (geographical coordinates and salient characteristics)
4. **Elaboration of Maps**
   - Elaboration of the map relative to charging station on main roadways
   - Elaboration of the map relative to charging station in coincidence of point of interest
5. **Elaboration of the scenarios of penetration and consequences**
   - On the basis of the data gathered two scenarios have been elaborate

2.2.3 Preliminary data

The collection of information started with the research and, where necessary, with the production of geographical data in GIS format and in a table form. For some categories it was possible to accede to public database in which the information were available in a useable and organized form, for other categories an accurate elaboration to transform the addresses in geographical coordinates, through the development of specific “macro” that are sustained by online cartographical systems publicly accessible was necessary.

2.2.4 Questionnaires and Mobility Manager

The questionnaire was prepared and submitted to the MM aimed at gathering information on the criteria of optimal location of charging stations and, in general, the spread of electric mobility at the people appointed by law to treat mobility. Even if around 230 MM were contacted from private company and the Municipalities of province of Brescia, the results were very scarce. The following points emerged:

- The economic component is the principal limit to the adoption of the EVs even if, it can be noted that the costs indicated for the administration of the conventional vehicles seem to be underestimated: it seems that an analysis of the "total cost of ownership" has never been done or at least the economic implication in the administration of the fleet was not really clear. This situation does not allow to properly assess the positive economic implications of the adoption of electric vehicles, especially for frequent and short travels.

- In general all the entities that have answered the questionnaire have one or more "ecological" vehicles (mainly fuelled by methane).
- Most of the organizations contacted identifies the parking area as the ideal location of electric charging stations, shifting the emphasis from the infrastructure of the roads.
- Many companies did not know that they have nominated a Mobility Manager.

2.2.5 Time plan and milestones

	Starting date				Finish date		Prolongation of the project			
	Feb.14	Apr.14	Jun.14	Aug.14	Sep.14	Oct.14	Nov.14	Dec.14	Jan.15	Feb.15
PA0										
PA1										
PA2										
PA3										
PA4										
PA5										
PA6										
PA7										
PA8										
PA9										
Milestones			Charging/storage station network Map	Charging / storage/provider Business model	Methodology	Regulatory setting proposal	Communication plan			

2.3 Implementation process

2.3.1 Expected results and outputs

The results of the pilot are collected in 4 main documents:

- **Two maps** were defined for the location of the recharge stations in the Province of Brescia; in summary, 22 stations along the roadway and 444 stations near poles which attract traffic allow the complete coverage of the territory of the Province, allowing all the EV to move freely without restrictions, overcoming the range anxiety. The location of the recharging stations is also polarized on the location of renewable energy plants;
- A collection of the **business model** identified for charging/storage service provider;
- A report with **regulatory proposals** and a **list of key-actions for the Public Administration** that should help the establishment of this new system of mobility and storage of electricity;
- The **detailed description of the methodology** used to obtain the results: this document can be used as a basis for the development of similar projects in other geographical locations, in Italy or abroad.

•Scenarios of penetration of the electric vehicles In Province of Brescia and at the national level.

• **A communication plan** which has the objective to promote the development of the electric mobility and recharging stations combined with the storage systems and the production of energy from renewable resources in the territory of the Lombardy Region. The communication and dissemination are essential to the success of the project throughout Lombardy Region. This result includes other outputs because it is a kind of trasversal action that involved the communication and explanation of the methodology, the businness models, the maps and a proposal of regulatory setting.

2.4 Scenarios

2.4.1 Renewable energy production and storage

As already said, Brescia in 2012 is the Province with the largest installed capacity of 5.8% of the 47.345 MW of the plants at the national level. In Lombardy Region, as per the Province of Brescia, the most productive and the most significant for the combination with storage are renewable energies from hydroelectric and photovoltaic plants[13]. The storage system applied to electric mobility, and in our case to the recharging infrastructure, is more effective where there are plants that produce a lot of energy and this energy is not totally consumed and where the storage could be used for the reduction of peaks of consumption. For that reason, in the pilot project, the recharging points were located also considering the proximity of the major hydroelectric[14] and photovoltaic[15] plants. For the hydroelectric plants, were chosen only the major ones in proximity to the road infrastructure. For the photovoltaic plants were chosen only the ones with a power over or equal to 1000 kW.

2.4.2 Scenarios of penetration of the electric vehicles

In the development of the pilot project an analysis of evolution of the EV in the system of mobility was carried out. The analysis is exclusively about the cars for private use and is applicable on a local scale in the Province of Brescia.

The methodology and the assumptions carried in these studies were summarized with data collected from the “central demographic scenario” elaborated by the ISTAT[16] and from the data relative to the rolling stock on the local level, obtained by the annual statistics of the Italian Automobile Club[17]. Next the procedure followed is illustrated and the results obtained are explained.

National and Provincial Level

The unison of the conclusions obtained in the cited publications permitted to elaborate the following forecast of penetration for the EV on a national basis. The application to the national scenario of the demographic indicators and the data relative to the rolling stockallowed the development of two scenarios “optimistic” and “pessimistic” on a local level, obtaining a detailed picture of the future electrical mobility, in the province of Brescia.

[13] Statistical Report 2012 - Plants in renewable sources - Electrical Sector ”, GSE S.p.A
[14] Data extracted from the platform “SILVIA – Sistema Informativo Lombardo per la Valutazione di Impatto Ambientale”, Regione Lombardia - http://www.cartografia.regione.lombardia.it/silvia/jsp/cartografia
[15] Data extracted from the platform http://atlasole.gse.it/atlasole/, GSE S.p.A
[16] “Il futuro demografico del paese” year 2011 – ISTAT – Resident population in Italy
[17] “Statistical Yearbook 2013” – Automobile Club Italia

(millions of vehicles)	2013	2020	2030
Optimistic Nat. Level	0,002554	3,8	10,0
Pessimistic Nat. Level		2,0	5,2
(vehicles)			
Optimistic Prov. level	Approx. 68	73’211	188’427
Pessimistic Prov. level		38’406	98’414

3 Main outcomes and benefits

3.1 Technical Findings

3.1.1 Map of the infrastructure

Assumptions for future charging network infrastructure in the Province of Brescia

- The priority of the location of the charging points was in relation and polarized on plants of production of renewable energy, in particular hydroelectric and photovoltaic plants, with a potential implementation of storage system.
- Only the charging points that are publicly accessible, meaning with that the structures operated by a service provider that have the exclusive aim of serving any electrical vehicle that needs to be charged.
- Only electric and hybrid plugin car that could circulate in the future on the streets of the Province of Brescia. This supposition in reality is not particularly restrictive, since they would actually be these vehicles to benefit like the principal users of the recharging structures that are publicly accessible, in respect to other vehicles that have an industrial or commercial use.
- Only private users, leaving out therefore the possible necessity of the public transport vehicles (such as taxi, car sharing...) and of the cars destined for company use. Even this choice is not a real limitation: the public transport vehicles and the company vehicles will probably use private charging points, and it would be the private users to principally make use of the network of charging station accessible publicly.
- The maximum detail considered is on municipal level, so the pilot did not take into consideration the location of the charging points inside every single municipality, delaying this definition to an eventual executive phase.
- “Isolation” of the Province of Brescia: in the development of the plan the Province of Brescia was considered exclusively, supposing that there are not any infrastructural projects for the bordering Provinces.
- For the purposes of the definition of the maps the type of charging stations (for example on the basis of power/speed of recharging, type of connectors, ...)was not taken into account: these details could be dealt with in the executive phase.

Criterion of localization

On the basis of the premises exposed above to the in depth analysis of the collected documentation, the following criterion of localization were established.

1- Charging on the roadways

- Type A road – Highways
- Type B road – main roadways
- Type C road – secondary roadways
- Renewable energy production plants with a potential implementation of storage system

2- Point of interest charging stations

- Industrial areas
- Commercial areas (marts, shopping centers, main cinemas)
- Public offices (hospitals, municipal houses)
- Public transportation hub (airports, railway stations)

3- Private charging points

- 1/8 ratio for public/private charging stations
- The localitazion depends on: distance from point of interest, urban density, trafic fluxes.

Three distinct typical stations can be identified. For the purpose of the definition of the maps, there were only considered the first two, supposing that the spreading of the private charging points (meaning both the residential as well as the company ones) follows "spontaneously" the diffusion of the EVs.

Map 1 – Motorways charging stations

The Map 1 (Figure 1) joins the recharging stations that would have to be put in exercise first, for the purpose of solving the problem of "range anxiety" in Province of Brescia and therefore enable a fast diffusion of the EVs. This necessity has to reconcile with the configuration of the complete network, in a second phase, that would probably bring these stations to be very little utilized. Following, the document reference is made to the classification of roads in Italy[18].

For the definition of the network of the Map 1 of charging station network (motorways charging station), the following hypothesis were defined:

- Maximum distance between the charging points is 30km;
- It is important to build a network, avoiding as much as possible isolated charging station meaning that a user has to be able to reach at least two second stations at a reasonable distance;
- Considering the proximity of the major hydroelectric and photovoltaic plants with a potential implementation of storage infrastructure.
- Considering only roads of type A, type B and type C.

[18] As defined by the Code of the Road:

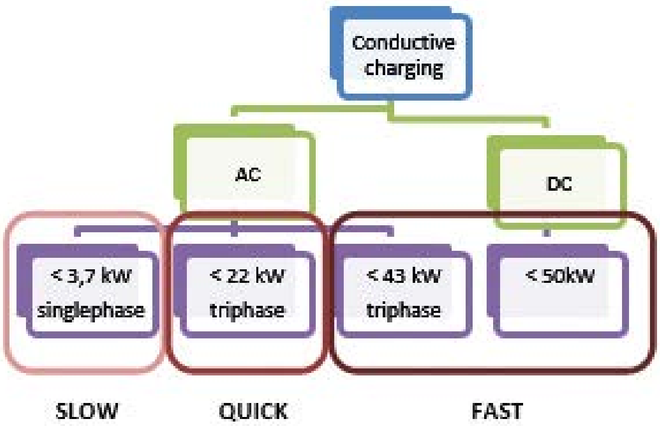
- Type A roads: extra-urban roads or urban with independent carriageways or anyway separated by a traffic divider, without intersections and private access;
- Type B roads: roads with independent carriageways or anyway separated by a traffic divider, each with at least two lanes and paved shoulder on the right, without intersections;
- Type C roads: roads with a single carriageway with at least one lane and sidewalk.

Map 2 – Point of interest charging stations

The Map 2 (Figure 2) joins all the locations of publicly accessible charging stations that could be activated, in a second phase, in order to complete coverage of the whole province of Brescia. The main part of the work consisted in the definition of the optimal positions of the charging stations, with the objective of allowing the charging of the vehicles in the points where these are “naturally” stopping for some time. The objective of this choice is the realization of a system in which each EV, every time that is in break, has the possibility to be recharged, eliminating the necessity of going specifically to recharge. The establishment of a scenario of this type would allow the complete overcoming of the “range anxiety” and would make the electric vehicles, actually, autonomous and comparable to the conventional vehicles. At the beginning of every trip the vehicle would have the battery completely charged, after every stop the vehicle would have recovered a substantial percentage of autonomy, so, while a conventional vehicle require always to plan a stop to refill, an EV with an efficient charging network will seldom require to plan a stop for recharge.

3.1.2 Typology of the recharging stations

Inside the technology of recharging we find an articulation that is quite complex between slow recharging (single phase or three phase) and fast (in AC or in DC), strictly tied to the technological evolutions that are characterizing this sector. In the following diagram the characteristics of the different possibilities of connection are revised. The speed of recharging, proportionate to the power are those indicated in the PNIRE.



No EV allows all the types of recharging. In particular all the vehicles allow the “SLOW” recharge and a fast way of recharging that could be “QUICK”, or else “FAST” type, in the two variations with continuous electricity or in alternate electricity. It must be noted that there are not relevant technological differences between the “FAST” and “QUICK” recharging stations: there is only a different dimensioning of conductors and interruption devices, and, for the “FAST” type, the recharge needs a wire connected to the station. The real difference is in the vehicle that can have the capacity to recharge with a higher or lower power. Today the vehicles on the market can be divided (even geographically) in two groups: with a few exceptions, in Europe the tendency is to accept recharges “FAST” or “QUICK” in alternate electricity, while in Japan and in the United States the use of the “FAST” recharging in a continuous electricity is becoming popular. It is to be noted that the construction of a recharging station in continuous electricity foresees the installation of an “inverter” (or “power converter”) that has the duty to transform the alternate electricity distributed on the electricity network in continuous electricity, precisely for the recharging of batteries. This device is expensive and relatively delicate. The EVs with the possibility of rapid recharge in CA have this device on board, while those that allow a rapid recharge in CC do not. A possible incentive to the diffusion of one of the two types derives from the observation that the number of public recharge stations will be much less than the number of vehicles spreading on the territory (of at least 10[19]). This means that the choice to realize such station in CC implies a cost that is globally inferior. However, some vehicles that are on the market today use their own technology on board, that has the duty to correctly nourish the electric motor, while moving, to convert continuous electricity into alternating. The emergence of this technology allows, with no additional costs for the station or for the vehicle, to obtain a quick recharge, with the distribution in alternate electricity.

The recharge in alternate electricity at a slow speed seems possible and convenient only in locations in which the vehicle stops for a lot of hours: it is therefore mainly for private parking or garage. Since the number of recharges that can be done in one day with low power is limited it does not seem to be economically sustainable to have this infrastructure on extended territory. From a deep analysis of all the collected documents we have come to the conclusion that, from a technological point of view, the best mode of recharging in public stations will be the ones identified by the PNIRE as "QUICK" and "FAST" in alternate electricity (therefore with power between 22kW and 45kW), even considering that the technology adopted for the charging station is the same, while it will be the vehicle to define the supply power.

3.1.3 List of key-actions for the Public Administration

The following listed policies are considered the possible normative interventions of Public Administrations focused on overcoming the barriers of E-Mobility development, besides the other related the support of storage and renewable energy infrastructures.

- European Level:
  - Clarify how the interface between the user and charging stations;
  - Setting standards for interoperability, aiming to connect the stations to remote servers, rather than in isolated systems.
- National level:
  - Definition of achievable goals (based on available resources) and stable for the next 10-20 years, then leaving the market free to evolve;
  - Capitalisation of several pilot projects that should be united under a single national platform;
  - Emphasizing the synergies between EV and new forms of shared mobility, especially in major urban centers;
  - Update Code of the Road;
  - Define the public utility of charging stations, cutting red tape/administrative;
  - Disseminate information and knowledge; central is the role of training (driving school, Departments of Motor Vehicles, etc).
- Regional/Provincial level:
  - Activate the Mobility Manager, transforming them from bureaucratic figures in real mobility operators;

[19] PNIRE defines the ratio between private and public charging stations in 1:8, while AFID state it should be 1:10.

- Urban planning;
- To bring technology closer to the people, entering EV vehicle in the parks of the PA and making the necessary charging stations, which are also publicly available;
- Promote the collaboration between public Administrations.

- Municipal level:
  - Introduce specific rules to the planning instruments for the dissemination of charging stations, recognizing them as urban elements with specific needs and characteristics;
  - Require the use of electric vehicles in those contexts that are already optimized for this new form of mobility.

3.1.4 Storage and electrical mobility

The fulfilment of an infrastructure for the recharging of electrical vehicles cannot today overlook a careful appraisal of the possibilities offered by “storage”, that is the accumulation of electric energy. Even this sector is characterized by a rapid technological evolution, a weak or inexistent regulatory setting and by investments of reasonable importance. In this setting two different modalities of accumulation can be distinguished:

- The installation of stationary batteries;
- The exploitation of the batteries of vehicles in a bidirectional way, to deliver power to the grid (modality known as vehicle to grid, or V2G).

It is necessary to underline that in the pilot project “Energy in Motion” the storage applied in electric mobility is considered in a unidirectional way, or better the flow of the energy is production, storage and consumption in EVs. This flow cannot have a reverse direction, so in “Energy in motion” is not preview the Vehicle-to-grid system.

Besides it should be made clear that the technologies of storage could satisfy numerous different exigencies, but in relation to the recharge of EV, only three possibilities can be pinpointed:

- Arbitration: decouple purchase and supply of energy for the recharge, exploiting the moment that cost less (less demand);
- Reduction of consumption peaks: supply energy for period of time between a few minutes and a few hours, to surpass the points of top up registered on the electrical network;
- In collaboration with the electric system, regulating the frequency, against variations of the load on the network.

As regards the stationary batteries, storage is applicable for arbitrage, for the reduction of consumption peaks and the reduction of frequency. Conversely for V2G storage is applicable only for the regulation of frequency. Supposing the business model “QUICK”, shown below, was effected an estimate of the economic impact of adoption of technology of storage. Since the market for these products is not organized and it is very difficult to establish precise parameters, the problem was faced on the other side, that is estimating the potential advantage obtainable thanks to the use of this technology.

3.1.4.1 Arbitration

Supposing that a service provider could acquire all the necessary energy to supply its clients on the market the day before, thanks to the exploitation of the storage technologies it could reduce the price of purchase of the energy. In particular it could acquire energy when the price is low, instead of following the needs of the clients. The advantage estimated it could obtain is equal to the difference between the medium price and the lower price registered on the market of the day before, every day. Such figures, obtained from public data from the Administrator of the Energy Markets for the year 2013, show that, for every kWh supplied, a saving between 4 and 5c€ is possible. This saving would be reduced to a proportional quota to the efficiency of the storage system (power converter and batteries), that is estimated as being equal to 70%. All this involves, for every complete recharge effected (36kWh), 1.18c€ less of the direct costs. Considering a single recharge station in use within the illustrated parameters in paragraph 3.2.3, that therefore aims to the attainment of the PBT in 5 years, the overall savings obtained by exploiting arbitration for the 2,136 recharges effected is guaranteed at 2,527€. The system of accumulation that permits the complete exploiting of arbitration should be able to store a quantity of energy that is equal to that necessary for the provisioning all the vehicles on the next day. Considering an average of 1.17 topups a day, it can be supposed that the quadruple value on the peak days and this would lead to a capacity equal to 168kWh, with the maximum power of about 22kW. To date a system of accumulation with these dimensions, based on lithium batteries, has a cost that is at least ten times higher in respect to the subsequent economic advantage.

3.1.4.2 Reduction of consumption peaks

Using a system of accumulation it is also possible to obtain some power extracted from the network. Hypothetically it would be possible to extract it in a constant way from the network electrical energy, to accumulate it in devices that allow the release in the moment in which to start a recharging operation. Following the same approach used for the estimate of convenience of the accumulation for the purposes of arbitration, it is supposed to optimize the withdrawal of power from the network in a way as to render it constant in the 24 hours. Following the results illustrated in paragraph 3.2.3, for a QUICK station, it would be necessary to withdraw a constant of about 2kW from the electric network, against a power of connection without accumulation equal to 22kW. This would lead to savings in the investments for a minor connection cost equal to approximately 1,000€, apart from the savings in the bill for a minor effort of power equal to 600€/yearly (considering an annual cost of 30€/kW). To maintain the return time set for 5 years, the system of accumulations should therefore have a cost of maximum 4,000€. The storage system that could allow the complete “levelling” of the loading profile should have a similar dimension to that already calculated for the arbitration, with the difference that would be constantly recharged at low power, to be discharged in full power the moment of re supplying. Considering an average of 1.17 recharging a day, it can be supposed a quadruple value in the peak days and this leads to a capacity equal to 168kWh, with a maximum power of about 22kW. Even in this case the conclusion is that today the application of a system of accumulation is not economically sustainable: the costs of acquisition of these devices should be reduced several times.

3.1.4.3 Frequency Regulation

The primary regulation of frequency does not lead, in the actual situation, to an economic advantage for the provider, at least until the Authority does not provide a specific compensation for this type of service effected on the network of distribution. Supposing however that the conditions utilized today for the power station with a nominal power > 10MW and not fuelled by non-programmable renewable sources, with reference to the period between April-December 2014, there would be the following compensations:

- For every kWh inputted in the grid for the purpose of the primary regulation there can be acknowledged a price on the market of the day before + 0.03963€
- For every kWh extracted from the grid for the purpose of primary regulation it will be approved a price equal to the price of the market of the day before – 0.02812€

Supposing that on average 20% of the energy needed daily for the vehicles could be utilized to make the primary regulations, in respect of the hypothesis illustrated in the model of business “QUICK”, the following economic advantages derive (clearly at the net of the price of acquisition of the energy):

- Compensation for the control to increase (insertion in the network): 121.85€/per year
- Compensation for the control to decrease (withdrawal from the network): 86.46€/year

With these advantages the cost related to the difference would be deducted between the energy withdrawn from the network and that inserted in the network, due to the loss of the double conversion between AC and DC for the recharging and discharging of the battery, as well as the efficiency of the same battery. The total economic advantage presumed to be equal to about 200€ does not justify any investment for the purpose of participating to the primary regulation, neither in the hypothesis of the adoption of specific stationary batteries, nor in the exploitation of the batteries on board the vehicles, in the V2G modality.

3.2 Economic effects

3.2.1 Business model

Even if the location of the charging points were established in relation to the location of renewable energy plants and storage systems in Province of Brescia, the analysis of the business model is the definition of the sustainable economic modes for the administration of the recharging service. The different typologies of the recharging stations have been analyzed and distinguished according to power and therefore speed.

3.2.2 Examples of business models and type of charging

In the matrix below different type of business models were analysed and compared, in relation to the type of the charging (QUICK, SLOW, FAST) for the development of the recharging infrastructure. There are a lot of possibility from the business model point of view, for example the charging station as an energy sales, as a service sales (service provider) and as a production of energy from renewable resources and the sales of charge service (i.e. a sort of SEU). This pilot project proposes the business model that previews the production of energy from renewable resources combined with the storage system and the sales of recharging service.

TYPE OF CHARGING	Utility (A2A)	Subscription and parking (ENERGY CAR)	Sponsor (EVBILITY)	Eletric car sharing	Renewable energy production and charge service sales (SEU)	Charging service sale included in other services	Production, storage and charge service sales (OIL&SUN)	Transport and Logistic (Energy-mob.)
SLOW	Domestic / Public	Public	-	Public	-	Public	-	Domestic / Public
QUICK	Public	-	Public	Public	Public	Public	Public	-
FAST	-	-	-	-	Public	Public	Public	Domestic / Public

3.2.3 Economic Analysis of the administration of the recharging points

It was clearly observed that, while the models QUICK and FAST could reasonably present an economic sustainability, it is not the same for the SLOW model that can never lead to an economically sustainable practice. Besides the cost to realize a QUICK point is mainly aligned to that of a SLOW point: this situations envisages with certainty the advantageous penetration of the points of QUICK recharge, that could eventually be administered by intelligent networks to reduce the power emanated to the vehicle in case of specific exigencies or critical situations of the grid.

With regards to the FAST charge station a paradox is registered. In fact such charging station seem to be necessary in an initial stage of penetration of the EV, when the charging network is not yet sufficiently extended to satisfy the needs of the users. The presence of these stations is therefore a qualifying element, because it allows to resolve the problem of range anxiety. However, when the network of station is completely realized, these points would result as being useless, or at least the users interested to this would be a lot less, clearly preferring QUICK or SLOW recharging effected in conformity to their own destination, in respect to the loss of the necessary time (even a few minutes) to effect a recharge during the trip. A good administration of the infrastructure should valuate attentively this aspect. The result of these observations leads to a scenario of the possible convergence between the three types of recharging toward the QUICK mode that shows the model of business that is more sustainable between the three that were analyzed.

Charging type		CA – SLOW	CA – QUICK	CC – FAST
Value		Routine	Capillarity	Autonomy
Value creation		Cooperation with parkings, LPT companies and monicipalities	Collaboration with commercial and industrial structures	Charging station on roadways, cooperation with regional administrations
Customer		Commuter	Occasional user	Innovators, early adopters
Cost/earning				
Equity		€ 3'150	€ 4'000	€ 53'000
PBT (year)		5	5	5
Direct energy cost	€ 0,15 36 kWh	€ 5,40	€ 5,40	€ 5,94
Maxi. Price	(VAT)	€ 7,00	€ 8,00	€ 14,00
for the customer:	(+VAT)	€ 6,36	€ 7,27	€ 12,73
Charging for recover the equity		3'269	2'136	7'809
Chargin/year		654	427	1'562
Charging/day		1,79	1,17	4,28

4 Conclusion

4.1 Regional potential of the tested local options

4.1.1 Qualification of the development of the charging station and storage system

“Energy in Motion” underlined several problems that have to be faced to qualify the development of charging station, storage system, renewable energy and the penetration of the electric car, and as much points that result on the other hand to be “red herring”: elements commonly deemed to be guilty for the reduced success on the market of the EV, but that in reality are not.

- Recharging infrastructure combined to the production of energy from renewable resources and storage are not developed because there is not a significant development of the electric mobility, even if this combination could be a very sustainable system from the economic and energy point of view.
- There exist no more technological limits to the spreading of the electrical vehicles[20].
- The economic limits tied to the overpricing of the electric vehicles to result are much overestimated in respect of reality.
- The electrical mobility does not have to be considered an experimental technology anymore.

4.2 Follow-up plans

As the follow up of the project we have two main objectives:

- **An implementation of the Communication plan** for the promotion of electric mobility combined to the exploitation of the storage through the charging infrastructure of the Lombardy Region.
- A **Regulatory setting** for the Lombardy Region that, thanks to its pilot experience could influence the regulations at the local, national and also European level.

The objective of the **implementation of the communication plan** is the promotion and information relating to the charging infrastructure to the widest possible audience. This action is fundamental for its success in terms of use and to attract numerous potential investors and operators. It is necessary to create and cultivate knowledge and awareness of the economic convenience (measured in total cost of ownership) of the choice of an electric vehicle, using renewable energies thanks to the storage system, together with the choice of using vehicles shared (car sharing).

The pilot project is not expected to influence only the sustainable mobility but inevitably, also renewable energy exploitation combined with storage, urban planning (public charging stations) and construction (charging stations inside private houses) at each regional scale.

The objective of the **regulatory setting** is a list of possible regulatory developments in the form of research, study and examination of:

1. Requirements of the operator, above all the promotion of a business model that previews the combination of energy production from renewable energy, storage and the sale of the energy produced (i.e. a sort of S.E.U. system) as an opportunity for the electric mobility and recharging stations;
2. Technical Standardization for electric vehicles and charging stations;
3. Incentives and “white credits”.

[20] Conference “JamBite” - Brescia June 25th, 2014 – Report of round table “mobility and networks.”

For these is proposed:

- Alignment of European legislation and key member countries (to identify a selection of countries on the topic);
- National legislation revision;
- Analysis and revision of rules of the Regions (i.e. Lombardy, Piedmont, Veneto and Trentino);
- Revision of European jurisprudence of the member countries and at national level.

1. Circulation (modification of the Highway Code);
2. Urban planning and permitting procedures.

For these is proposed:

- National legislation revision;
- Analysis and revision of rules of the Regions (i.e. Lombardy, Piedmont, Veneto and Trentino).

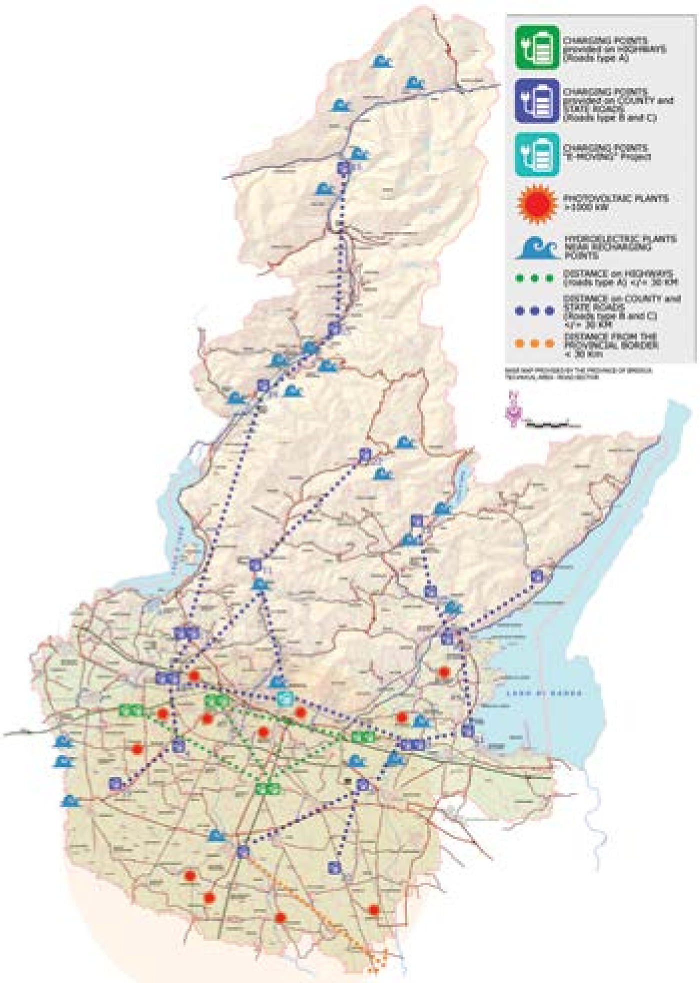


Fig. 1 - Map 1 - motorways charging stations

Exhibition	★	5
Health facilities	●	32
Cinema	▲	43
Railway stations	*	56
Shopping centers	★	81
Methane service stations	★	21
Municipalities	☆	206
TOTAL		**444**

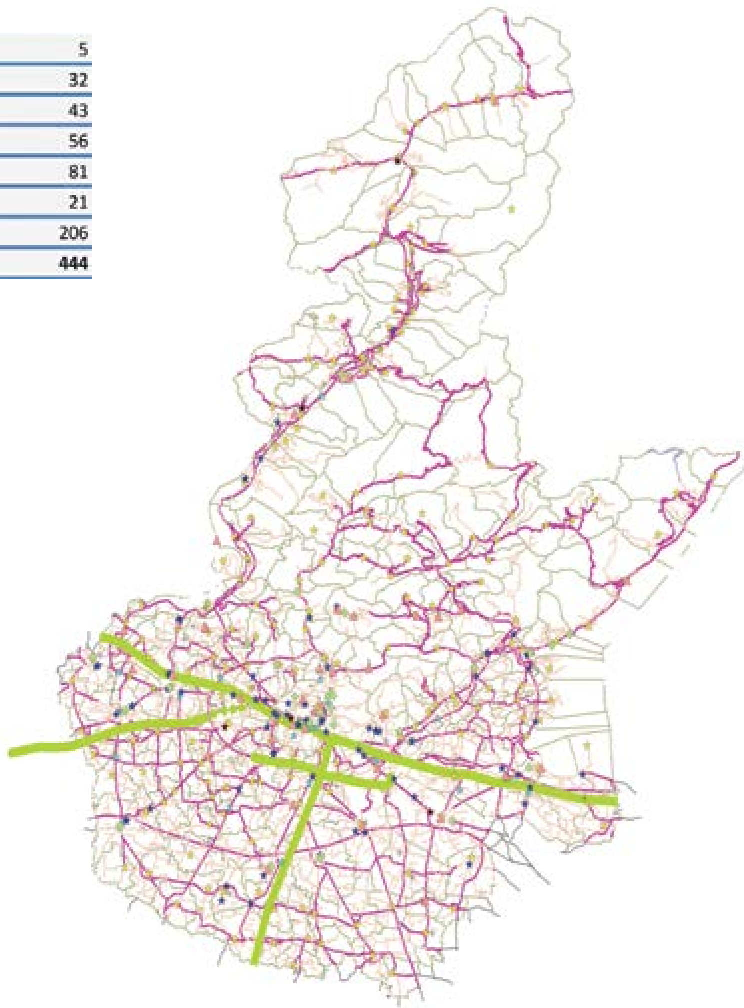


Fig. 2 - Map 2 - Point of interest charging stations

4.3 Transferability to other Alpine regions

As already described in chapter 2.2.2, the **methodology** used **in the pilot project** was analyzed in order to facilitate who would want to follow the same path to develop the optimal architecture in a web of recharge in other geographical zones in synergy with and as an opportunity to support the development of renewable energy production, storage systems and E-Mobility.