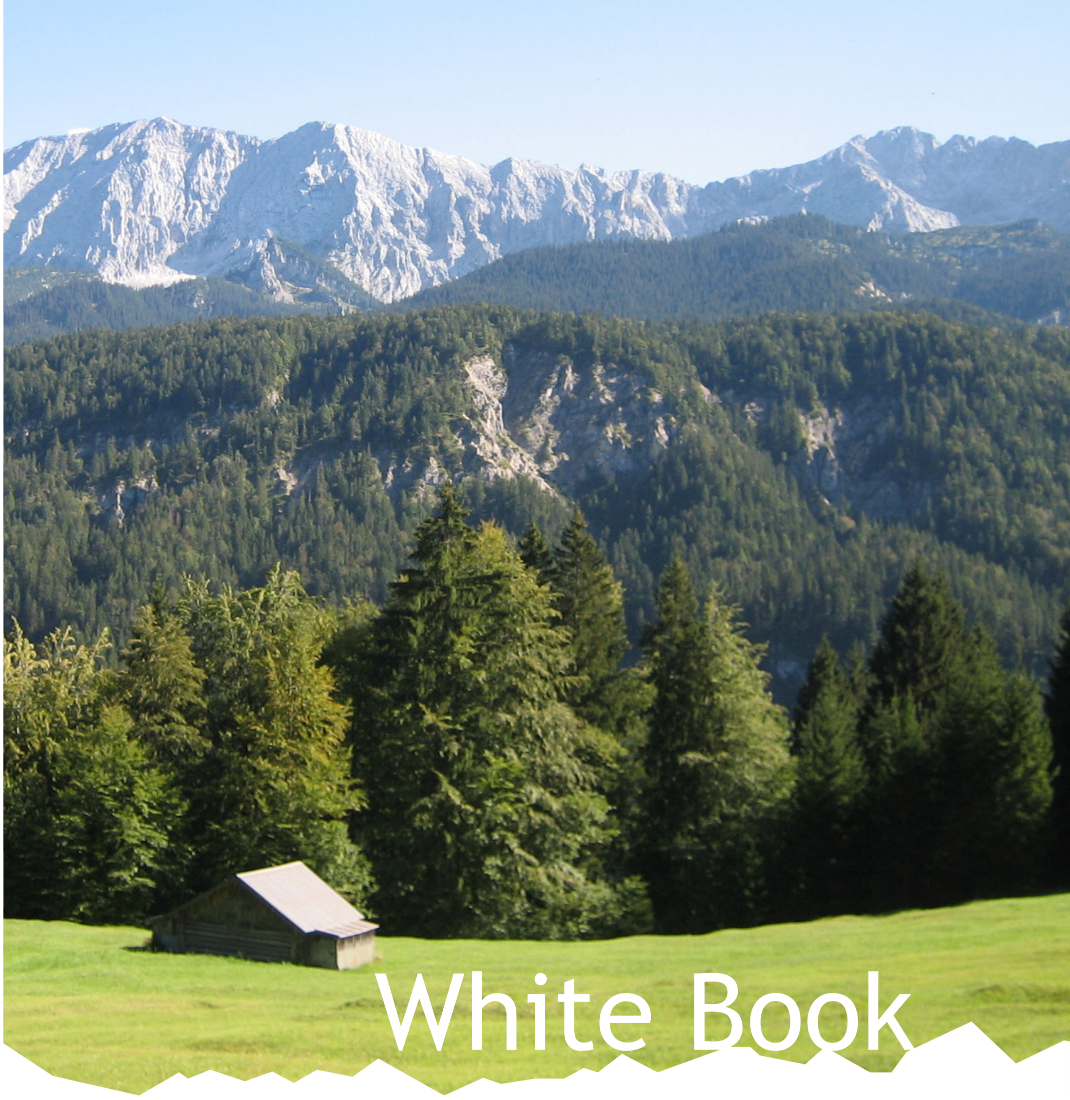

White Book

Smart Storage and Mobility (STORM)

ALPSTORE

Alpine SPACE

EUROPEAN TERRITORIAL COOPERATION

THIS PROJECT IS CO-FUNDED BY THE EUROPEAN REGIONAL DEVELOPMENT FUND

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Energy Storage for the Alpine Space

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List of acronyms and abbreviations

AS	Alpine Space
BEMIP Electricity	Baltic Energy Market Interconnection Plan in Electricity
CAES	Compressed Air Energy Storage
CHP	Combined Heat and Power
DC	Demand Control
DHS	District Heating Systems
DSM	Demand Side Management
EC	European Commission
EEG	Erneuerbare-Energien-Gesetz
ESS	Energy Storage System
EV	Electric Vehicles
GW	gigawatt
GWh	gigawatt hour
HTTESS	High Temperature Thermal Energy Storage Systems
HV	High Voltage
LV	Low Voltage
MV	Medium Voltage
MW	megawatt
MWh	megawatt hour
NSI East Electricity	North-South Electricity Interconnections in Eastern Europe
NSI West Electricity	North-South Electricity Interconnections in Western Europe
NSOG	Northern Seas Offshore Grid
OSI	Open System Interconnection
PHEV	Plug-in Hybrid Electric Vehicle
PPP	Public Private Partnership
PV	Photovoltaic
R&D	Research & Development
RE	Renewable Energy
RES	Renewable Energy Sources
ROI	Return on Investment
SNG	power-to-substitute natural gas technology
STORM	Smart Storage and Mobility
toe	tonnes of oil equivalent
V2G	Vehicle to Grid
kWp	kilowatt peak
kWh	kilowatt hour
TWh	terra watt hour
ReNEP	Resolution on the National Energy Programme
TEU	Treaty on the European Union
TFEU	Treaty on the Functioning of the European Union

1. Summary

In order to be secure, reliable, affordable, non-detrimental to the climate and ecologically friendly, energy supply has to be based on renewable energies (RE) on a worldwide scale until 2050 at the latest. A major contribution to energy supply can be provided by technologies converting solar radiation and wind power into electricity which can also be used to cover not only the demand for electricity, but also for heat, cold and transport by means of heat pumps, cooling devices, and electrical vehicles.

The maximum instantaneous power, that can be provided by solar and wind power plants, depends on the weather and is therefore strongly intermittent. Storage is one means among others to match such intermittent generation to the electricity demand in place and time. Alternative, respectively complementary options are:

- fine-tuning of the generation mix to maximise the mutual compensation of generation fluctuations,
- grid extension and reinforcement which allow for mutual compensation of generation and demand variations appearing at the same time, but at different places,
- demand side management which changes the electricity demand time-profile in order to better match with generation,
- and generation management which consists in over-dimensioning of generation facilities and operating them for times of low demand below the nominal output.

Generally, stores are elements of energy conversion chains, which provide a buffer between two forms of energy (i. e. supply in times of low generation). They can often equally well be used for energy provision and for/or Demand Side Management (DSM), i. e. consumption in times of excess power generation to stabilize the grid. Stores can also link the main energy vectors electricity, heat, and gaseous fuels. All these interdependencies need to be taken into account when investigating storage comprehensively in order to derive conclusions for an overall optimised future energy system.

Against this background, this Whitebook describes

- the renewable energy situation and storage demand of all Alpine Space countries,
- the potentials of storage technologies at hand, and
- pathways to “Smart Storage and Mobility” – STORM.

The Whitebook builds on the results of AlpStore at about half time of the project. At the time of its publication AlpStore partners are in the midst of their research and deployment activities. Final guidelines of the project will be published in early 2015. They will describe the ultimate findings and give guidance to local and regional authorities, regional energy utilities and Investors. Nonetheless, it is worthwhile to use the information given in this Whitebook to structure the discussion process. Moreover, chapter 9.3 contains “Short-term non-regret options for players in Alpine regions”.

2. AlpStore: the project

Sun, water and biomass are a natural capital of the Alpine Space. It is necessary to use them for the production of energy. Besides intelligent grids, storage systems will be key enablers for a future mostly renewable energy supply.

Electric vehicles (EV) will be integral elements of the future energy system. Their batteries can be charged with excessive power from intermittent energy sources and electricity can be fed into the grid to meet peak loads. Beyond short term balancing with EVs, stationary batteries can serve long-term balancing needs. They can give EV batteries a “second life” and improve overall economy of electric mobility. Other media such as gas or compressed air will add more choices.

Partners in seven countries (Table 1) create master plans for the deployment of storages. Pilot tests will show the feasibility of mobile and stationary storage in public infrastructure, business parks, enterprises and smart homes. From there guidelines for planners and decision makers will be derived. In the following, the objectives of the project are explained in more detail:

- Using storage and electric vehicles in the energy provision system will become key in ensuring stable energy supply in all Alpine regions. With reliable energy provision, regions stay attractive as living habitats, working spaces and recreational sites.
- The transnational AlpStore team develop the STORM-concept (see chapter 9). 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 will be 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 shows how electric mobility brings improvements for the AS connectivity and new business opportunities. Integrating mobility into the energy system can close the cost gap of electric mobility. To assess these opportunities AlpStore compare battery EVs with gas and hydrogen solutions.
- Twelve test site implementations with a variety of stakeholders and AS technology firms provide reliable input to sensitise political and business decision makers for new opportunities in the combined field of mobility and energy provision. Test sites for the development of policies. They offer visiting tours and experience exchange workshops. Two big conferences in Italy and Germany shall attract more than 500 participants.
- The comprehensive communication concept involves research and technology transfer institutions and a big group of observer. The STORM concept and lessons learnt in 12 regions will be published as guidelines for decision makers.

For more information about the project, pilots, activities, news, resources etc. please visit www.alpstore.info.

Table 1 - Project partners and contact information

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Kraftwerke Oberhasli AG (KWO) / Battery Consult GmbH	urh@kwo.ch

3. A methodology for putting the puzzle together

3.1 Storage – a means to an end

Energy storage is not an end in itself, but a means to an end. 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 RES on a worldwide scale by the middle of the 21st century at the latest. An analysis of the potentials of different RES shows that a suitable mix of RE technologies 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.

3.2 The need for an integrated view on storage

For putting storage into perspective and for getting a better picture of its role in a mainly renewables-based energy supply system, it is helpful to consider in more detail the very basic function of storage: to provide a buffer for stabilising energy flow between its source and the facility. Examples of such energy buffers are:

- Coal, petrol, natural gas, biomass, biogas etc. which are chemically bound energy in a form that still needs conversion. Hence, stores for these materials are energy stores at the beginning of the conversion chain. Such stores must exist for matching the fuel exploitation and their use. For instance, fossil fuels are exploited more or less constantly, and biomass is harvested mainly in summer, but fossil fuels and biomass are both used mainly in winter.
- Hot water tanks, district heating grid lines, etc. which store thermal energy thus matching the heat generation and use.
- Rotating masses in thermal power stations that store huge amounts of energy in form of rotational energy, which serves as spinning reserve for stabilising the frequency of the electric grid.
- Cold stores, freezing warehouses or liquefied gases that store energy services (the provision of cold).
- Compressed air in pressure bottles and tanks storing mechanical energy, which can directly be used wherever compressed air is needed, e.g. for motion in industrial processes.
- Batteries, which convert electrical energy into chemical energy when being charged and back into electrical energy when being discharged.
- Capacitors and inductors in electric equip-

ment, which provide a buffer for electrical energy in electric circuits.

This list shows that examples of storage where electricity is converted into another form of energy and then back into electricity are rather the exception. Basically, energy stores can be divided in four categories:

- Stores for solid, liquid or gaseous energy carriers;
- Stores converting electrical energy in another form of energy and back into electrical energy;
- Stores for thermal energy converting power on heat into chemical energy and back into heat;
- Stores for energy in the form in which it will be used, i. e. at the end of the energy conversion chain.

The same store can be used in different ways. Compressed air stores can for instance just be used for increasing the existing compressed air buffer capacity in industrial facilities, thus allowing for more flexibly operating the compressors and for making use of arbitrage if the compressor capacity is also increased. This case falls in the category of Demand Side Management (see chapter 6.2.2) and is normally not considered as storage. However, it is not much different from the case where (a part of) the compressed air is re-expanded to operate a turbine that drives a generator.

The example of compressed air shows that the whole picture of storage options and their interdependence with energy generation and use is quite complex. An overview of the most important interdependencies is given in Figure 1:

The diagram distinguishes notably gas (grey), electricity (blue), and heat (red). Facilities that convert energy between these forms are indicated by diagonally divided two-coloured squares. It illustrates that an overall optimisation of the energy system requires an integrated view of the different energy sources, use cases and vectors, notably the grid-bound energy vectors electricity, heat, and gas.

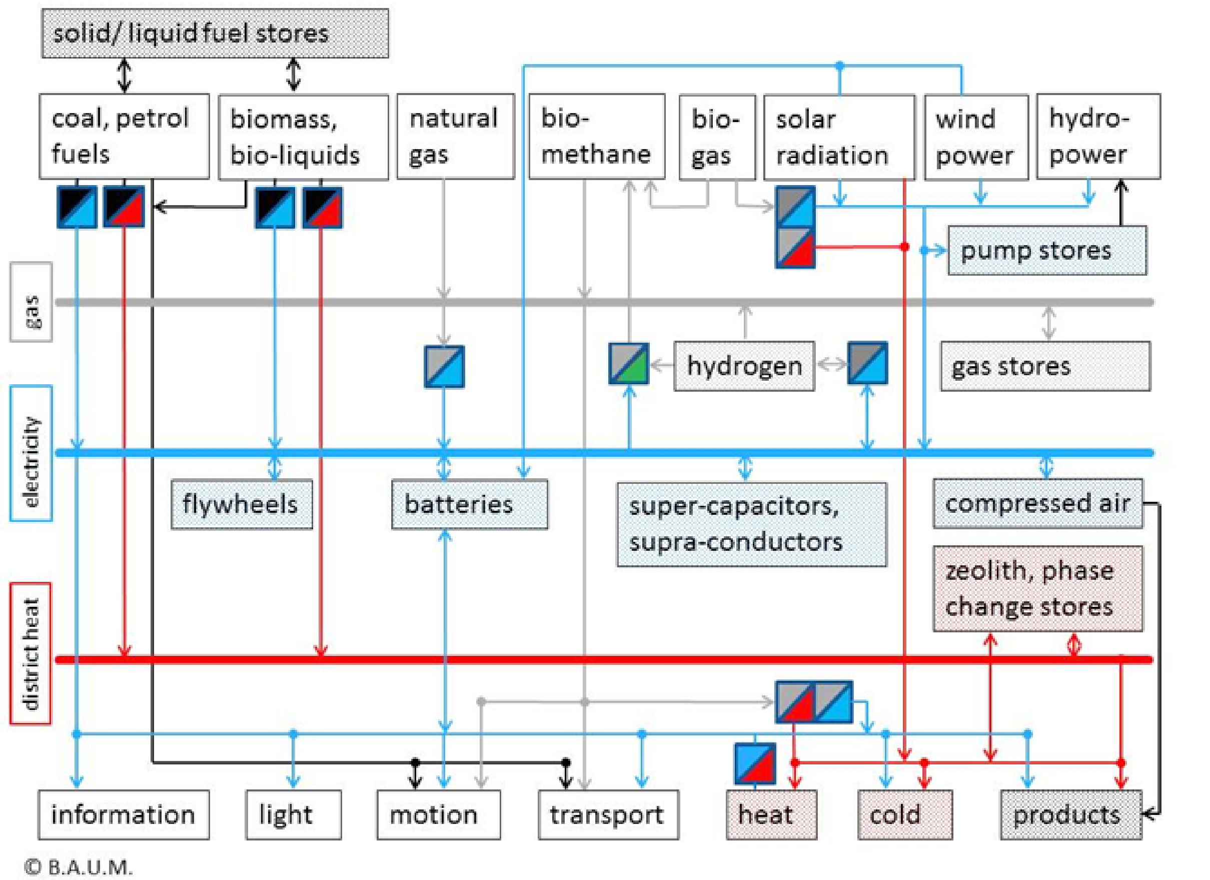

Figure 1 - Energy pathways with energy storage, source: (B.A.U.M. Consult GmbH, 2013)

3.3 Energy storage in the context of the Alpine Space

The Alpine Space (AS) is predestined for multifaceted decentralised generation of power from renewable energy sources (RES). Many of those are intermittent and power usage must better adapt to generation. While demand side 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 electro-mobility both for decarbonisation of transport and development of RES”. The EU 2020 flagship initiative for a resource-efficient Europe strives for joint efforts concerning the use of ICT for a smart energy system. 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 PPP.

While the extension of pumped hydro storages meets natural and societal barriers, other technologies can bring added value to homes, towns and regions. No realistic storage scenario taking into account technological, societal, geographic and climatological characteristics of the AS has been evaluated. 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 assesses which mixture of technologies will best fit the AS needs. It prepares the implementation of combined storage and mobility concepts in regional and municipal planning.

4. Development of renewable energy use and storage in the Alpine Space

4.1 Renewable energy generation

Figure 2 shows the proportion of electricity generated from renewable sources in 2011 for the Alpine countries. Electricity generated from renewable energy sources contributed one-fifth (21.7 %) of the EU-27's gross electricity consumption. In Austria with 66.1 % and Switzerland (non-EU) with 54.5 %, more than half of all electricity consumed was generated from renewable energy sources, largely from hydropower and biomass.

Table 2 (page 13) shows the primary production of renewable energy 2000 and 2010 and the percentage share of the RES. The primary production of renewable energy within the EU-27 in 2010 was 166.6 million tonnes of oil equivalent (toe). The primary production of renewable energy within the EU-27 in 2010 was 166.6 million tonnes of oil equivalent (toe) — a 20.1 % share of total primary energy production from all sources. The quantity of renewable energy produced within the EU-27 increased overall by 72.4 % between 2000 and 2010, equivalent to an average increase of 5.6 % per year.

Among renewable energies, the most important source in the EU-27 was biomass and waste, accounting for just over two thirds (67.6 %) of primary renewables production in 2010. Hydropower was the other main contributor to the renewable energy mix (18.9 % of the total). Although its level of production remains relatively low, there was a particularly rapid expansion in the output of wind energy, which accounted for 7.7 % of the EU-27's renewable energy produced in 2010.

The largest producer of renewable energy within the EU-27 in 2010 was Germany, with a 19.6 % share of the total. There were (also are) considerable differences in the renewable energy mix across the Member States, which reflect to a large degree natural endowments and climatic conditions. This also illustrates Table 2. For example, more than three quarters of the renewable energy produced in Germany was from biomass & waste (78.7 %), while more than one third of the renewable energy of Austria and Slovenia was from hydropower. Close to one-third (29.2 %) of the renewable energy production in Italy was from geothermal energy sources (where active volcanic processes still exist).

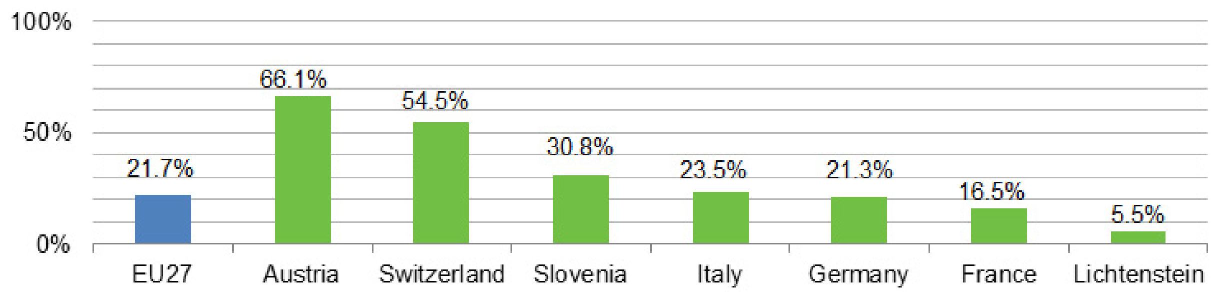

Figure 2 - Proportion of electricity generated from renewable sources in percent of gross electricity consumption 2011, source: (European Commission, 2012), (Energie Zukunft Schweiz, 2011), (Government of Liechtenstein, 2013)

Table 2 - Primary renewable energy use for production of electricity, 2000 and 2010, source: (European Commission, 2012)

Country	Primary renewable energy use of production of electricity (1000 toe)		Share of total RES, 2010 (in %)				
	2000	2010	Solar energy	Biomass & waste	Geothermal energy	Hydropower energy	Wind energy
EU 27	96,650	166,647	2.2	67.6	3.5	18.9	7.7
Austria	6,608	8,600	2.0	57.1	0.4	38.4	2.1
France	15,874	20,793	0.5	69.1	0.4	25.6	4.1
Germany	9,094	32,746	4.4	78.7	1.6	5.4	9.9
Italy	9,598	16,928	1.8	37.3	29.2	26.9	4.8
Liechtenstein	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Slovenia	788	1,041	0.6	59.5	2.7	37.3	0.0
Switzerland	4,437	4,968	1.0	31.3	5.2	62.4	0.1

The output of renewable energy in Germany grew at an average rate of 13.7 % per annum between 2000 and 2010. The rapid expansion of primary production of renewable energy in Germany meant that it become, by far, the leading producer by 2010.

Figure 3 shows the combined heat and power generation (CHP) in percent of gross electricity generation in 2011 for the Alpine countries.

CHP from renewable energy sources contributed about one-tenth (11.2 %) of the EU-27's gross electricity generation. In Austria (15.7 %), Germany (13.1 %) and Italy (11.5 %) the percentage of CHP of the gross electricity generation is above the EU-27's average. France has the lowest share of CHP of the gross electricity generation with about 2.8 % of the gross electricity generation.

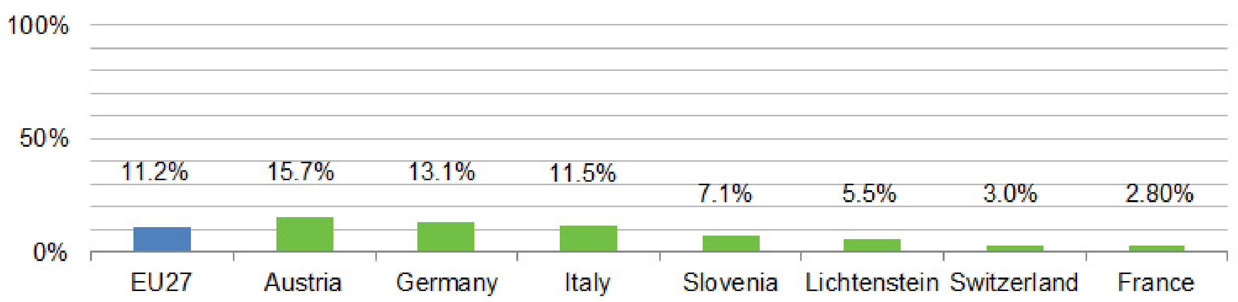

Figure 3 - Combined heat and power generation in percent of gross electricity generation 2011, source: (European Commission, 2012), (Energie Zukunft Schweiz, 2011), (Government of Liechtenstein, 2013)

4.2 The need for storage

At present, the PV electricity generation at midday has reached a level of power, which leads to a strong offer and subsequent reduction of spot market prices for electricity. This leads to more constant residual demand and electricity prices than before, when the demand and spot market prices peaked at noon. It reduces the need for, and profitability of, pump storage systems and gas 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.

In 2012, VDE in Germany published its study “Energy storage in power supply systems with a high penetration of renewable energy sources” which explains that beyond a threshold of 40 % renewable energies storage systems will be significant for the operation of transmission grids. However, the study gives little information on storage systems to better manage local bottlenecks in the distribution grids. To be prepared for a RE penetration of 80 % and beyond, the VDE calls for extensive investigation of storage technology and deployment.

The VDE study is one among many others, which come to a similar result: given intelligent grids more flexibility in generation and demand, storage will not be needed 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. Long-term (seasonal) storage will even not be required until the RE-share has reached 80 %. However, comprehensive modelling results, which take into account the whole range of options for adapting RE-based electricity generation to the electricity demand and the interdependencies between the electricity, heat, gas and fuel sector, are still largely missing.

Another conclusion of the VDE study is that the storage of energy is very expensive at the moment. The storage of electrical energy causes significant costs from 3 ct/kWh for short-term storage to 10 ct/kWh for long-term storage. Nevertheless, the absence of less costly storage should not be considered as a reason for delayed expansion of renewable energies.

A further conclusion from the existing studies is that there will be a much larger need for long-term storage than for short-term storage for which many alternatives exist (demand side management, generation management, etc.). The only feasible option for long-term storage at this stage is conversion of electrical energy into chemical energy of hydrogen and methane and store it in the existing natural gas stores and grid.

5. Backgrounds for a mainly renewables-based energy supply

The following chapters are based on national status quo and framework studies executed by AlpStore partners in 2013. These national framework studies are available on the Alp-Store Internet platform (www.alpstore.info).

5.1 Austria

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 among the four EU countries with the highest share of energy from energy from 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 to 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 15.98 Mio. tons (CO_2 equivalent) in Austria in the 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 Figure 4 (see page 16). Detailed information about the institutional and legal framework for Austria can be found in the country-specific framework on the AlpStore homepage.

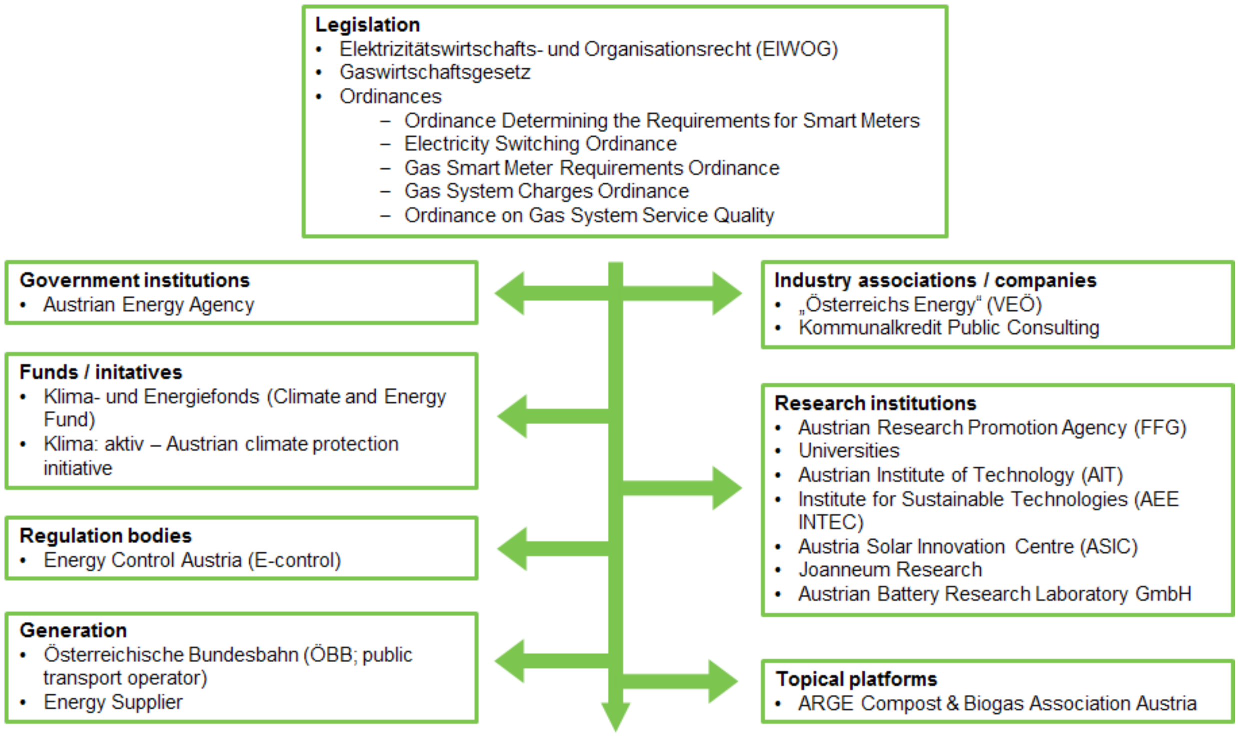

Figure 4 - Institutional / legal framework Austria, source: (Keglovits & Hartmann, 2013)

5.2 France

The renewable energy share in France production has been 14.6 % in 2011, RTE forecast for 2016 is 18.3 %. The renewable energy plan for France defined by the Grenelle de l'environnement framework presents measures to achieve an increase to 23 %, by 2020, of renewables as a share of gross energy consumption (in line with EU Directive 2009/28/EC).

- **Energy production mix:** The French energy production mix is dominated by nuclear generation and despite the increase in renewables share will still represent 72 % in 2020 and 67 % in 2030. While the mix structure in France results in a very competitive energy price compared to other European countries, it also offers very limited flexibility.

- **Shutdown nuclear power plant:** The French government also decided to close the nuclear power plant in Fessenheim in 2016. The two reactors of this plant provide an output of 900 MWe each. This represents two thirds of the energy consumed in Alsace region. The AlpStore roadmap for Alsace could represent an interesting contribution to a post-Fessenheim energy landscape.

- **Electrical system:** France electrical system is specific because of the nuclear generation contribution to the mix but also because of a high gradient sensitivity to cold weather. The gradient of sensitivity to cold weather is the increase in power consumption depending on the decrease of temperatures, especially in winter. In France in 2011, this gradient corresponds to 2,300 MW per degree of decrease of minimum temperature. This value is greater than the sum of the gradient of the continental European countries.

- **Power demand:** Electrical heating is a key component of the residential demand in France. The exceptional value of peak winter demand in France (92 GW in 2009) compared to other European countries (73 GW in 2009 for Germany). This peak power demand is increasing every year and the rate is 21 % between 2001 and 2010. RTE forecast for 2020 is 108 MW, which translates in a 35 % increase since 2001. One major consequence is that France is importing electricity for a highly larger number of days in the year.

• **Wind farms:** In 2010, the French government released a call for tenders for the installation of 95 MW of wind farms on French islands. The technical specifications of this tender required storage technologies to be integrated to the wind generators, in order to promote the emergence of technologies that reduce the impact of wind turbines to the power grid, and make possible a significant increase in the share of renewables in the intermittent electricity production of these territories, currently limited to 30 %.

• **Photovoltaic:** The government has also launched in 2011 a call for tenders for the photovoltaic power exceeding 250 kWp. It has a lot dedicated to specific for ground solar installations located in Corsica or in the DOM, and integrating storage devices of the energy produced. The specification includes the conditions for energy storage and the daily forecasted production to be met.

A compressed overview for the relevant institutional and legal framework provides Figure 5. Detailed information about the institutional and legal framework for France can be found in the country-specific framework on the AlpStore homepage.

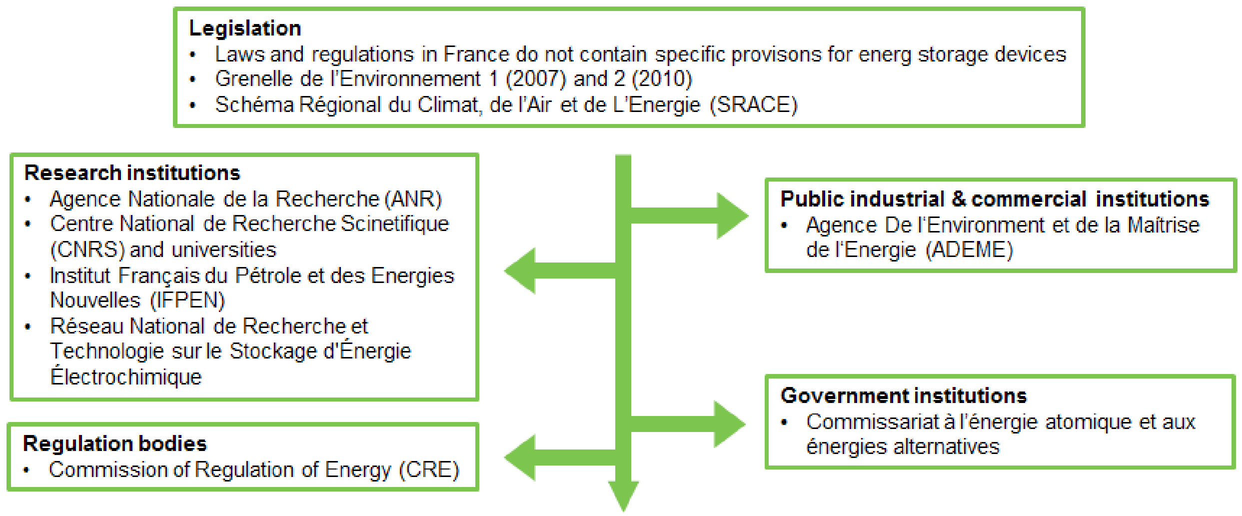

Figure 5 - Institutional / legal framework France, source: (FRESHSMILE, 2013)

5.3 Germany

The total installed electric power generation capacity in Germany was 176.5 GW as of 1 February 2013. Out of this, 74.6 GW (42.3 %) were renewable power generation capacity by incident almost exactly the maximum consumption load of the German electricity system at that time. The largest generation capacity is provided by PV installations (32.5 GW, 18.4 %), followed by wind power generators (30.3 GW, 17.2 %) and hard coal power stations (20.2 GW, 11.4 %).

• **Renewable electrical energy generation:** In terms of energy, the contribution of renewable energies to the total electricity generation was 22.6 % in 2012.

• **Electricity mix:** The contributions of renewables to the overall electricity generation were 4.6 % form PV, 3.3 % from hydropower, 6.6 % from biomass, and 7.3 % from wind power, the contributions of non-renewable energies 11 % from natural gas, 19 % from hard coal, 16 % from nuclear, and 26 % from lignite.

• **Photovoltaic generation:** The PV generation capacity in Germany is about one third of the worldwide installed capacity (103 GW at the end of 2012).

• **Wind power generation:** The German wind power generation capacity is about 10 % of the worldwide installed capacity (284 GW) at the end of 2012.

• **Investments:** The development of RE electricity generation in Germany is going along with considerable investments (19.5 bn € in 2012). Investments peaked in 2010 and decreased afterwards, notably because of the strong decrease of PV module prices since 2009.

- **Ownership structure:** The four large electricity suppliers owned only 5 % of the RE generation capacity by the end of 2012. Private persons (11 % directly owned by farmers, 35 % by other private persons) and smaller companies (14 %) own the largest share of generation capacity. Project developers own 14 %, smaller energy suppliers 7 % and funds and banks own 13 % of the generation capacity (other 1 %).

- **Energy cooperatives:** Increasingly, RE plants are owned by energy cooperatives whose number has been strongly rising since 2008. In the last three years, there has been a quadrupling of energy cooperatives, from 144 in 2008 to 586 in 2011.

- **Job creation:** In 2012, the RE sector (electricity, heat and transport fuels) provided 378,000 jobs. Most jobs existed in the biomass sector and were related to the production of fuels from agriculture and forestry. The number of jobs has been steadily increasing over the last years.

- **EEG – Renewable Energy Act:** The EEG guarantees operators of RE electricity plants a minimum price, which is to be paid by the grid operator for the electricity, generated and fed into the grid. The logic behind the EEG is that the guaranteed feed in tariff provides sufficient investment security for a large number of potential investors.

- **Grid parity:** The point where the PV generation costs crossed the average household electricity tariff is called grid parity. This point was reached in 2011. From that, PV electricity was cheaper than electricity purchase for households and it was cost-effective to cover as much as possible the own consumption by self-generated PV electricity. By mid-2013 electricity form roof top PV plants costs only half of the average household tariff (28-29 ct/kWh) and about one third of the electricity of newly installed PV plats is consumed by the operators themselves.

- **Return on investment PV:** The underlying assumption in the Framework Germany for the calculated PV electricity production costs is that the ROI is 6 %.

- **Need for reforming the European electricity market:** RE electricity generation decreases spot and future electricity market prices. Large consumers pay even 40 % less for electricity since 2011. Market prices do not reflect life-cycle costs, but marginal costs. Another effect is that the difference between maximum and minimum spot market price (arbitrage) has been strongly reduced in the last years. A consequence of the midday peak demand shaving by PV electricity and the resulting strong reduction of arbitrage at the electricity markets is that already existing storage facilities can no longer be cost-effectively operated.

- **End consumer prices:** The strong decrease of electricity prices at the spot and future markets is largely not reflected by the end consumer prices for electricity. End consumer prices have been constantly rising over the last decade – except for large industrial companies, which can purchase electricity. The average in 2013 of household electricity tariffs is estimated to be 28.7 ct/kWh.

- **Cross-border effects:** 2012 Germany was a strong net exporter of electricity again. Exports of electricity from Germany were 66.6 TWh, imports 43.8 TWh and the net export 22.8 TWh in 2012.

- **Present need for storage:** The PV 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, thus leading to more constant residual demand and electricity prices than before, when demand and spot market prices peaked at noon. This situation will not persist and storage systems will be needed very soon at much larger scale than ever.

- **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.

- **First generation of 100 % RE regions:** Germany has already a long tradition of communities and entire regions being dedicated to the aim of 100 % RE-supply of their area. One of the first regions, which officially set this aim, was the District of Fürstenfeldbruck in Bavaria close to Munich, which is aiming at 100 % RE-supply until 2030. More than 100 other communities and regions in Germany followed the example of Fürstenfeldbruck. In September 2013, the network 100 % RE regions comprised 138 districts, communities and regional agglomerations totalling 21.6 million inhabitants and an area of 108,000 km^2.

- **Second generation of 100 % RE regions:** From 2007 to 2012, the Ministry of Economy and Technology has financed the flagship programme “E-Energy: ICT-based energy system of the future. One of the six model regions has been the District Harz in Saxony-Anhalt. The RegModHarz project has shown that a combination of generation units, stores, flexible consumers, and the grid can ensure a reliable electric energy supply with a very high rate of RE. More specifically, a number of issues such as the forecast of generation and demand, the control of a large operation, flexible operation of biogas plants, load management in private households, and different marketing strategies were studied in details within simulations and field tests.

A compressed overview for the relevant institutional and legal framework provides Figure 6. Detailed information about the institutional and legal framework for Germany can be found in the country-specific framework on the AlpStore homepage.

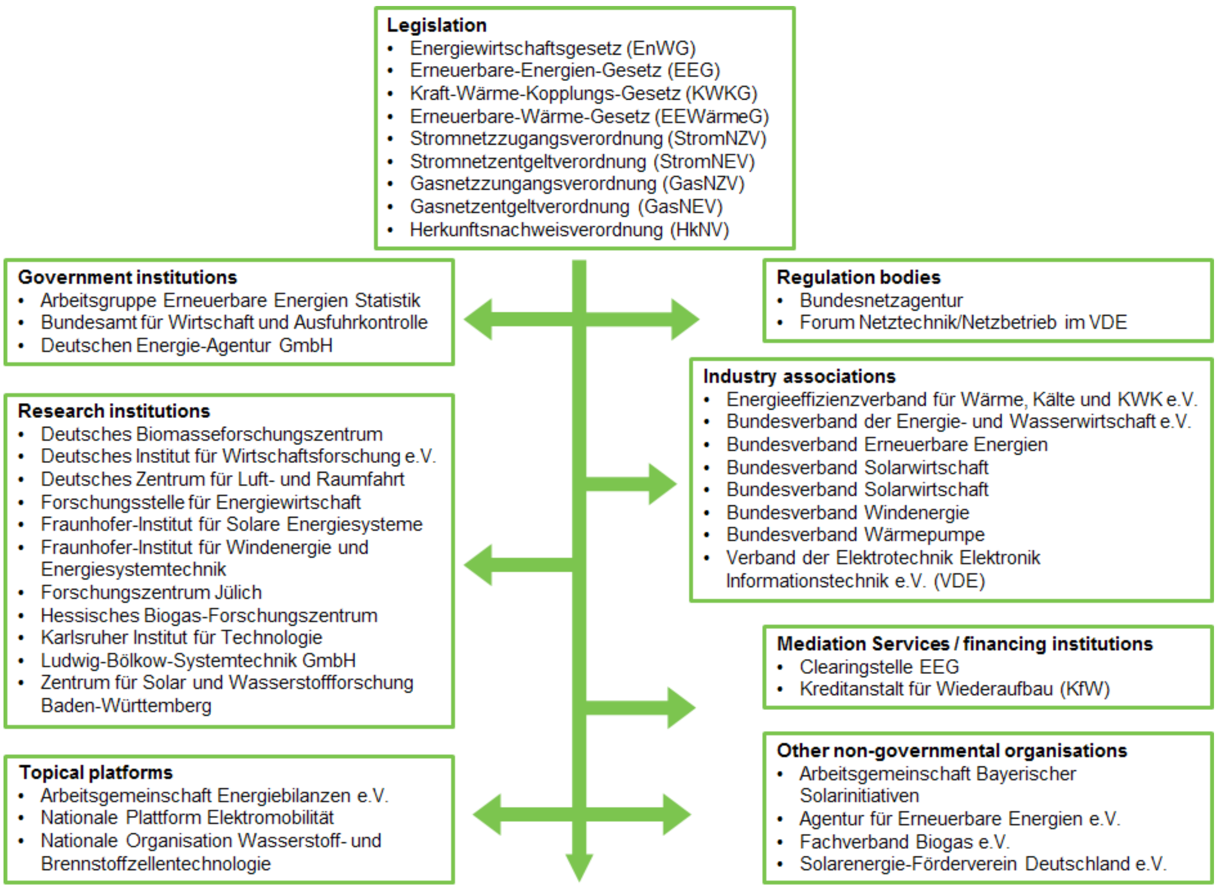

Figure 6 - Institutional / legal framework Germany, source: (Stöhr, 2013)

5.4 Italy

The total installed electric power generation capacity in Italy is higher than 100 GW in face of half of peak power demand. The largest generation capacity is provided by thermal power generation (54.7 %), followed by hydropower generation (14.3 %) and wind, PV and geothermal power generation (7.3 %). The net import/export balance take part with 13.7 %.

- **Dispersed Generation (DG):** DG is defined as a set of power plans with rated power lower than 10 MW and connected to the distribution grid, both Medium Voltage (MV) and Low Voltage (LV); the DG location is usually uncertain and power injections are unpredictable.
- **Small Dispersed Generation (SDG):** SDG is a set of power plants for electrical energy production, including cogeneration systems; with sizes up to 1 MW (this is a subset of DG).
- **European Network of Transmission System Operators for Electricity:** The 2013 winter report of the ETSO-E demonstrate that Italy could export energy to border countries inverting its own energy rule if compared with the current energy scenario.
- **Energy flows across the Italian grid:** Italy typically imports energy from France and Germany, consequently the grid has to support a power flow from the North to the Middle of the Country. On the other side, the South of Italy has very poor energy consumption and, simultaneously, a very rich availability of power plants using renewable (and non-renewable) resources; such a scenario leads to a power flow from the south to the middle of Italy.
- **Gross production of electricity from GD in 2010:** The gross production of electricity from GD in Italy amounted to 19.8 TWh (about 6.6 % of the national production of electricity), an increase of 3.4 TWh compared to 2009.
- **Number of GD plants:** The number of DG plants is equal to 159,876, with a gross efficient power of 8,225 MW (about 7.5 % of the national gross efficient power); while in 2009 the in-service power plants were 74,188, with a gross efficient power of 5,644 MW (about 5.4 % of the national gross efficient power). The increase in the number of GD plants is mainly due to solar power plants (in detail, photovoltaic plants increased from 71,258 in 2009 to 155,977 in 2010); with regards to other energy sources: hydroelectric power plants increased from 1,904 in 2009 to 2,385 in 2010, thermal power plants increased from 902 in 2009 to 1,224 in 2010 and wind farms from 124 in 2009 to 290 in 2010.
- **Further GD plants:** In 2010, a rated power equal to 2,299 MW of hydroelectric plants were installed, they produced 9.4 TWh (47.3 % of production from GD), 2,191 MW of thermal power plants which produced 7.8 TWh (39.5 % of production by GD), 458 MW of wind farms that produced 0.8 TWh (3.9 % of output by GD) and 3,277 MW of photovoltaic plants which produced 1.9 TWh (9.3 % of output by GD).
- **Energy sources used for the production of electricity from GD:** In 2010 74.6 % of the electricity produced by GD was from renewable sources. The main renewable energy source is hydroelectric production with an amount of 47.4 % of the total DG production. Considering the RES, water is the most used with an incidence of 16.9 %.
- **DG photovoltaic plants:** DG photovoltaic plants show an exponential increase of the number of photovoltaic plants in 2011. In the same way, the installed power has increased (from 3,277 MW in 2010 to 12,225 MW in 2011) and the energy has increased (from 1,853 GWh in 2010 to 10,346 GWh in 2011). In 2011 325,081 photovoltaic power plants were connected to the network with a total power of 12,685 MW and a total energy production of 10.9 TWh.
- **Installed renewable electrical power 2011:** Hydro 18.1 GW, wind 7 GW, solar 12.78 GW, geothermal 0.77 GW, bio energies 2.8 GW, biomass 1.29 GW, biogas 0.77 GW, bio liquids 0.76 GW. In total, 40.4 GW electrical power was installed in 2011.
- **Energy produced by renewable sources 2011:** Hydro 45,822.7 GWh, wind 9,856.4 GWh, solar 10,795.7 GWh, geothermal 5,654.3 GWh, bio energies 10,832.4 GWh, biomass 4,730.2 GWh, biogas 3,404.7 GWh, bio liquids 2,697.5 GWh. In total, 82,961.5 GWh were produced in 2011.

A compressed overview for the relevant institutional and legal framework provides Figure 7 (see page 21). Detailed information about the institutional and legal framework for Italy can be found in the country-specific framework on the AlpStore homepage.

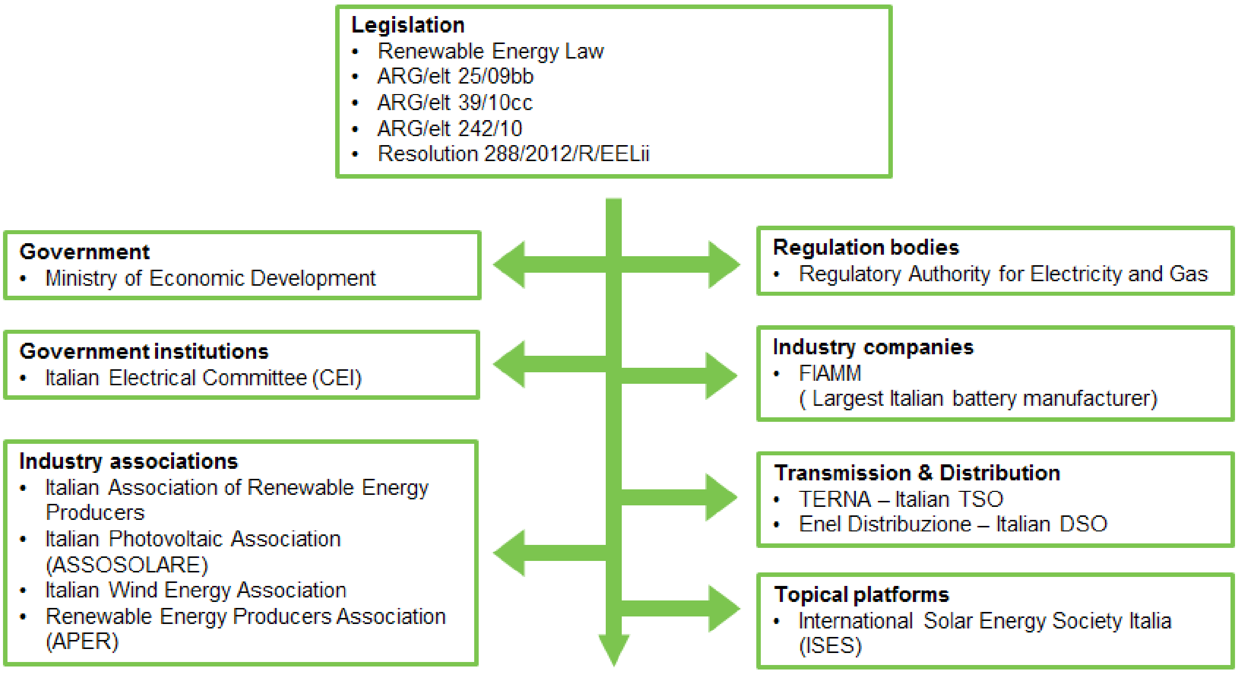

Figure 7 - Institutional / legal framework Italy, source: (Minelli, et al., 2013)

5.5 Liechtenstein

The latest paper from the government of Lichtenstein is called **Energiestrategie 2020**, which removes the Energiekonzept 2013 and builds up on the successes of this former concept paper. Energiestrategie 2020 is a handbook to establish concrete measures for a save, sustainable and affordable energy supply for the Principality of Lichtenstein until the year 2020. Core contents are the renovation of the building sector, the mobility sector, increasing energy efficiency, reconsider the energy production and import and the campaign “Energieland”.

- **Status quo renewable energy self-supply:** Liechtenstein covers its energy needs with 9.8 % with renewable energy in 2011. For this calculation are include: Eleven hydroelectric power stations, the combined heat and power unit in Bendern driven by biogas and 773 solar power stations (PV), but also heat production by local firewood and over 1594 thermal heat collector systems. In totally the amount of energy-self supply with resources from Liechtenstein was 128,899 MWh in 2011. The production in eleven hydroelectric water power stations covers around 18 % of the whole electric energy demand of Liechtenstein. In total, this is around 72 GWh.

- **Research project “Erneuerbares Lichtenstein”:** Main aim of the research project was to replace non-renewable technology by regenerative energy production, whereas only systems were allowed, which can be used in Liechtenstein. In short, the target was to look at Liechtenstein as an island and supplying the country only with renewable energy. The result of the research was that a complete regenerative self-supply can only be established by carefully targeted and specific efforts. This aim could be reached in around 60 years. In the heating sector an amount of 62 % and in the electric energy an amount of 78 % could be reached by regenerative energies intra muros.

- **Research project IBAER:** IBAER is the follow-up project to the well-known research projects “Erneuerbares Lichtenstein” and the BAER-projects (Bodensee-Alpenrhein Energieregion). This FFF-bases project deals with the opportunities of an international building exhibition for the Bodensee-Alpenrhein region and launched officially on 1 October 2013 at the University of Liechtenstein.

A compressed overview for the relevant institutional and legal framework provides Figure 8. Detailed information about the institutional and legal framework for Liechtenstein can be found in the country-specific framework on the Alp-Store homepage.

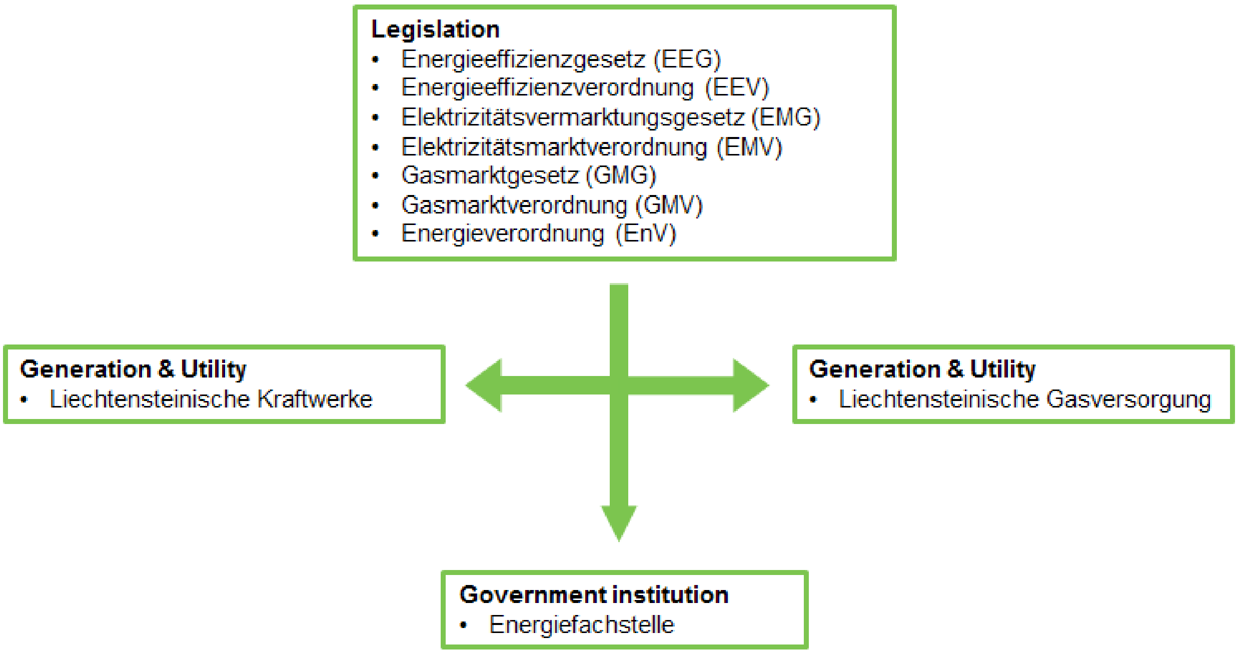

Figure 8 - Institutional / legal framework Liechtenstein, source: (Droege, 2013)

5.6 Slovenia

The Resolution on the **National Energy Programme** (ReNEP) – which was implemented in 2004, defines the mechanisms for promoting renewable energy sources and sector goals for renewables up to 2010. The new National Energy Programme, which is in the final stage of drafting and should replace the existing ReNEP, will define the goals of energy policy up to 2030 and the mechanisms for implementing these goals, including the targets Slovenia has set itself in the EU climate and energy package up to 2020 and other international obligations.

- **Objectives of Slovenia's energy policy:** Ensuring a 25 % share of RE in final energy consumption. 10 % share of renewables in transport by 2020. Implementing efficient energy use and RES as economic development priorities. Increasing the share of RES in final energy consumption (long term).
- **Governmental support to achieve the RES objectives:** Adequate support environment for energy rehabilitation of existing buildings and construction of active buildings, replacing heating oil with wood biomass and other RES, district heating systems bases on RES and heat/power cogeneration, increasing the share of railway and public transport, introducing biofuel and other RES in transport and farming and electric vehicles. The last one is the developing of distribution networks for incorporating dispersed electricity generation, including the development of active/smart networks and the developing industrial production of technologies for efficient energy use/RES.
- **Hydropower:** Hydropower plants have the largest share among the RES in Slovenia (28.7 % of the total electricity production in 2009). Besides the large hydroelectric generating units, there are approximately 400 small units (2006) with a total capacity of 85 MW. The technically feasible hydropower potential of the Slovenia is estimated to 8,800 GWh/p.a. of which a third has currently been exploited. An additional 40 MW

of small hydro capacity is also estimated to be unexploited.

• **Biomass energy:** Forests cover more than 56 % of the Slovenian territory. 6 MW of CHP plants utilising solid biomass was installed in 2004, with a view to increasing this up to 11 MW by 2020 stated in the National Energy Programme. Biogas also holds a considerable potential, with 6 mostly agricultural biogas plants with a total installed capacity of 3.4 MWel.

• **Wind energy:** A large number of potential sites for wind power in the country are situated in ecologically sensitive mountain regions, which are under consideration for national parks. Approximately 40 MW of wind capacity is in the planning process. The total estimated power generation potential for the country, as of 2006, was 600 MW.

• **Geothermal energy:** The north-eastern portion of the country has the greatest geothermal resource. Installed capacity amounted to 49 MWth in 2005. Geothermal energy is not currently utilised for electricity generation.

• **Solar energy:** Studies have shown that with existing technologies Slovenia can harness 960 GWh per year, which is about half the power Krško nuclear power plant produces at the moment. The total installed capacity of photovoltaic installations was 120 MW in 2011. Average daily insolation across the country is above 1000 kWh/m^2.

A compressed overview for the relevant institutional and legal framework provides Figure 9. Detailed information about the institutional and legal framework for Slovenia can be found in the country-specific framework on the AlpStore homepage.

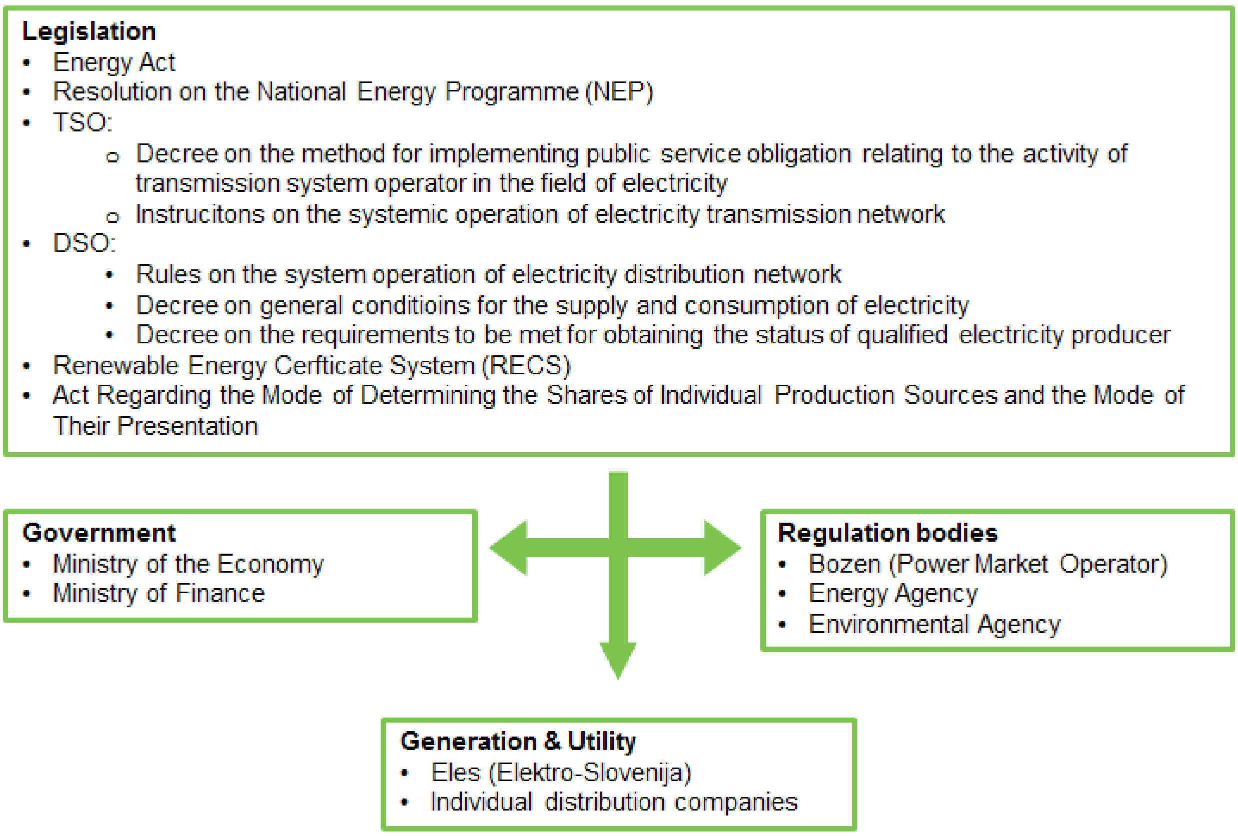

Figure 9 - Institutional / legal framework Slovenia, source: (Droege, 2013)

5.7 Switzerland

The Energy Strategy 2050 defines the Swiss renewable energy policy. The Federal Council intends to continue to maintain Switzerland's high level of electricity supply security even without nuclear energy in the medium term. This was the decision taken at its special meeting on 25 May 2011. Existing nuclear power plants are to be decommissioned when they reach the end of their service life, and will not be replaced by new ones.

- **Supply Security:** In order to guarantee supply security in the future, the Federal Council is focusing on increased energy efficiency, the expansion of hydropower and use of new RE, and, where necessary, on fossil-fuel-based electricity production (combined heat and power plants, gas-fired combined cycle power plants) and imports.
- **Electricity grids:** Switzerland's electricity grids are to be expanded immediately and energy research is to be intensified.
- **Cleantech Masterplan:** The Cleantech Masterplan serves as a situation analysis and should lead to greater coordination in terms of resource efficiency and renewable energies.
- **Road Map - Renewable Energies Switzerland:** This document, produced by Swiss Academy of Engineering Sciences, predicts growth of electricity produced by renewable sources.
- **Electricity production:** Currently, Switzerland obtains around 55 % of its electricity production from RE. Mostly this production accounts for hydro plants while the production using other renewable source (such as wind, sun, biomass etc.) is still below 1 % of total production.
- **Goals of the Agency for Renewable Energy and Energy Efficiency (A EE):** Exploiting all potential efficiency by actively shaping the policy and regulatory environment, protecting the environment, promoting the economic and innovation in Switzerland, creating sustainable jobs and across the federal, cantonal and municipal level and across borders. A EE aims at bringing together industry associations, utilities and research/innovation institutions in order to make them work synchronously towards the mutual aim of increase of energy efficiency and renewable production growth.
- **Smart Grid:** A first Smart Grid project has been established in Ittigen in collaboration of BKW, Swisscom, Swiss Post, IBM CH and local community.

A compressed overview for the relevant institutional and legal framework provides Figure 10. Detailed information about the institutional and legal framework for Switzerland can be found in the country-specific framework on the Alp-Store homepage.

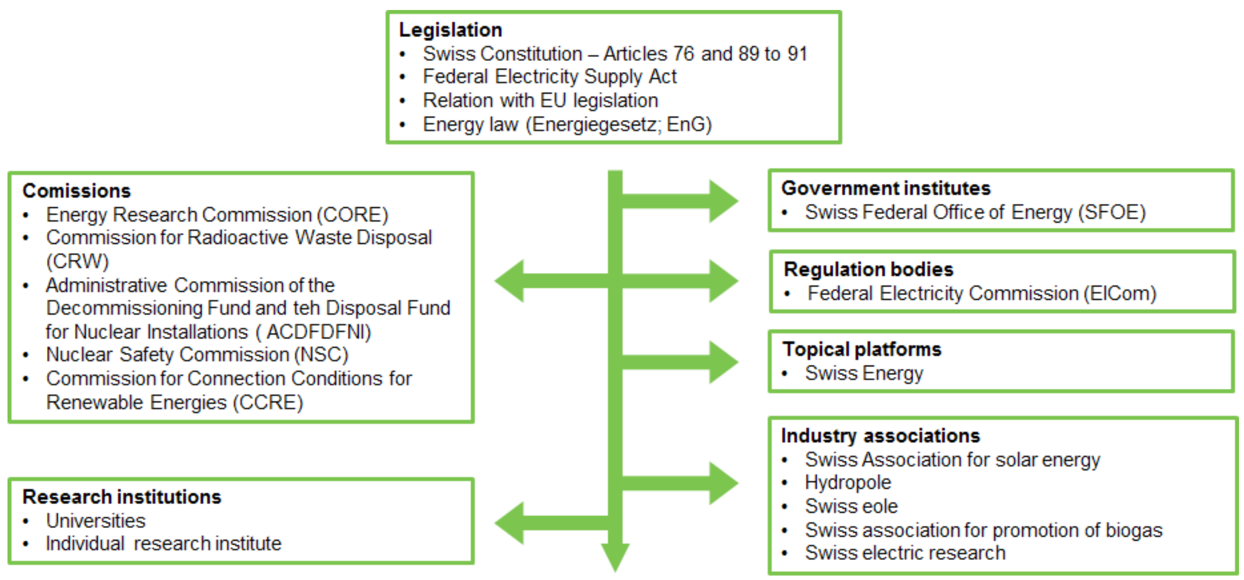

Figure 10 - Institutional / legal framework Switzerland, source: (Lukovic & Ursin, 2013)

5.8 European Policy Framework

Europe 2020

Within this Whitebook, five major targets for the EU's growth strategy "Europe 2020"are concerned (see Table 3).

The third target (20-20-20 until 2020) is the main driver for all EU activities in the field of renewable energies including energy storage. It can also be found in earlier documents than those relating to the Europe 2020 strategy and it has entered in several EU legislative and other documents.

A compressed overview for the relevant policy framework provides Figure 11. Detailed information about the policy framework for the European Union can be found in the EU-specific framework on the AlpStore homepage.

Table 3 - Targets Europe 2020, source: (Stöhr, 2013)

Targets	Definition
Employment	• 75 % of the 20-64 year-olds to be employed
R&D	• 3 % of the EU's GDP to be invested in R&D
Climate change and energy sustainability	• Greenhouse gas emissions 20 % (or even 30 %, if the conditions are right) lower than 1990 • 20 % of energy from renewables • 20 % increase in energy efficiency compared to the reference year
Education	• Reducing the rates of early school leaving below 10 % • at least 40 % of 30-40-years-olds completing third level education
Fighting poverty and social exclusion	• At least 20 million fewer people in or at risk of poverty

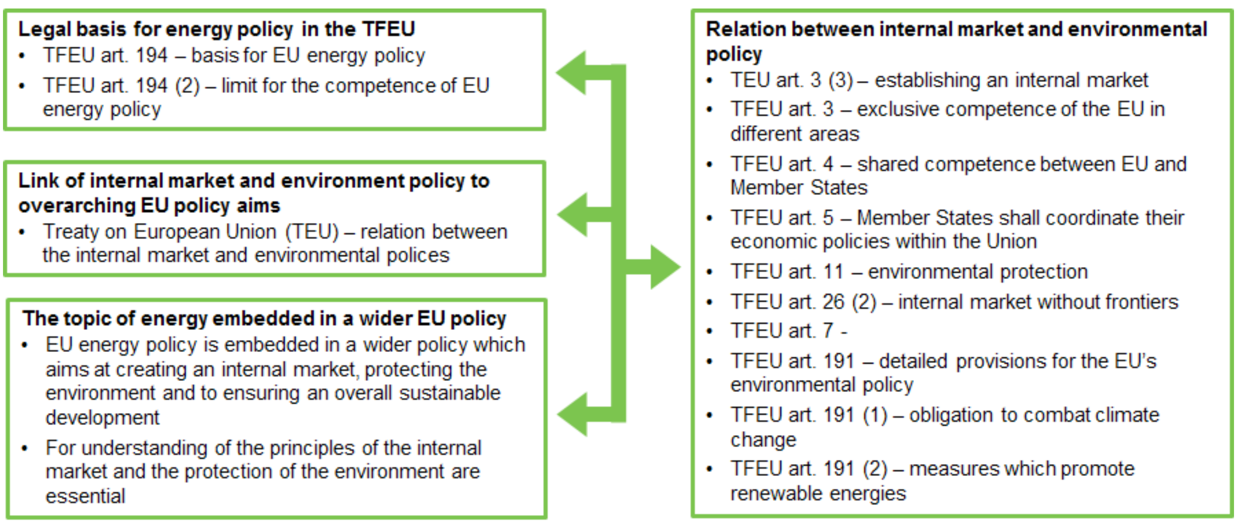

Figure 11 - Policy framework European Union, source: (Stöhr, 2013)

6. Storage Technologies

6.1 Market overview and future options for storage

The tables in this chapter provide a condensed overview and assessment of the various storage technologies in the respective countries. Similar to the institutional and legal framework, for more detailed information just have a look at the country-specific framework. The assessment given in respective tables is based on national status quo and framework studies executed by AlpStore partners in 2013.

Explanations

- Market availability: +++ (highest), ++, +, o (medium), -, --, --- (lowest)
- Storage volume: +++ (highest), ++, +, o (medium), -, --, --- (lowest)
- Local option: +++ (highest), ++, +, o (medium), -, --, --- (lowest)
- Storage period (typical resting time): minutes, hours, days, weeks, months
- Response time (speed to load and unload the store): very quick, quick, medium, slow, very slow

6.1.1 Biogas digesters and storage tanks

Biogas storage tanks in combination with an enclosed pressure vessel, a digester and a combined heat and power unit form a complete biogas energy plant. Most available models feature a stiff steel or concrete ring and a flexible cover.

Local storage of biogas: Biogas is essentially a mixture of CH4 (methane) and CO2 (carbon dioxide) 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

Table 4 - Biogas digesters and storage tanks

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	+++	days	+	medium	+++
France	--	days	+	medium	+
Germany	+++	days	+	quick	+++
Italy	+++	weeks	++	medium	++
Liechtenstein	+	days	+	medium	+++
Slovenia	++	days	+	medium	+++
Switzerland	+++	days	+	medium	+++

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 plant is not situated in the vicinity of the existing natural gas grid or is not big enough to allow for economically viable up-grading of biogas to bio-methane (almost pure CH_4). 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 biogas output rate.

Local storage of 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 electricity-led mode and the electricity production is strongly fluctuating, e.g. because the CHP produces balancing energy to stabilise 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 electricity-led compared to the usual operation at more or less constant power (i. e. in the base load mode; see further below in this section: electricity production from biogas). 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 ratio of electricity and heat production. This leads however to a lower overall CO_2 reduction because the electricity production per unit of biogas is no longer maximised and renewable heat avoids less CO_2 than renewable electricity as long as the power plant mix is still dominated by fossil power plants.

Local storage of up-graded biogas (bio-methane): Biogas can be up-graded to bio-methane through almost complete removal of all other gases than CH_4, notably removal of CO_2. Bio-methane 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 bio-methane. This option is only of interest if the use case requires the almost complete removal of all other gases than CH_4. 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 exists and the storage has no role in the electricity grid management.

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 after pressurising 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 a 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.

Table 5 - Biogas digestion, up grading to bio-methane, and storage in natural gas grid and stores (only Germany)

Country	Market availability	Storage period	Storage volume	Response time	Local option
Germany	+++	months	+++	quick	+++

6.1.2 Power-to-Gas

Methane in gas grid: A massive gas grid for natural gas supply links large areas of European, countries and regions. This system could be used for the storage and transportation of bio- or renewably produced methane.

The power-to-gas (P2G) conversion technology, more precisely power-to-substitute natural gas (SNG) technology, is at present the only pathway that allows seasonal storage of major amounts of energy by making use of existing stores. Efforts to promote P2G include the promotion of SNG and of hydrogen as energy stores and fuels because the production of hydrogen from renewable power is the first step of the P2G process to SNG. However, hydrogen is more suitable than SNG if the mass needs to be kept low, e.g. for transport applications, notably in aerospace, but SNG is more suitable if the storage volume is limited.

The strongest advantage of SNG compared to hydrogen however is, that it easily fits with the existing norms for natural gas relevant for fuelling vehicles and for transport and storage within the existing natural gas infrastructure. As the energy transfer capacities of gas pipelines are an order of magnitude larger than electrical power lines, the conversion of electrical energy into chemical energy in form of SNG does further allow for energy storage, but also for much more efficient energy transport.

Hydrogen in gas grid: If hydrogen is directly used as storage medium and not converted to SNG, one energy conversion step, the Sabatier process, can be omitted and related energy losses can be avoided. However, only limited amounts of hydrogen (in Germany up to 5 %) can be fed into the existing natural gas grid or added to natural gas that is used as vehicle fuel. Establishing a specific grind and storage infrastructure for hydrogen today seems to be out of scope.

Table 6 - Power to Gas – methane in gas grid

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	o	weeks	+++	quick	o
France	---	weeks	+++	quick	+
Germany	+	months	+++	quick	++
Italy	--	weeks	--	quick	++
Liechtenstein	--	weeks	+++	quick	o
Slovenia	o	weeks	+++	quick	o
Switzerland	o	weeks	+++	quick	+

Table 7 - Power to Gas – hydrogen in gas grid

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	o	weeks	+	quick	--
France	---	weeks	+	quick	--
Germany	+	months	+++	quick	++
Italy	---	weeks	---	quick	--
Liechtenstein	--	weeks	+	quick	o
Slovenia	---	weeks	+	quick	--
Switzerland	o	weeks	+	quick	-

Hydrogen local: This connotes local energy storage in gas form. This could be done at different scales - for example in vehicle fuel tanks, stationary fuel tanks or in large salt domes or mines.

Table 8 - Power to Gas – hydrogen local

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	--	days	-	quick	+
France	---	days	-	quick	+
Germany	+	days	+	quick	++
Italy	--	days	--	quick	-
Liechtenstein	--	days	-	quick	o
Slovenia	---	days	-	quick	+
Switzerland	--	days	-	quick	+

6.1.3 Chemical energy storage

Chemical storage systems involve the storage and release of thermal energy through reversible chemical processes. For example, zeolites are microporous aluminosilicate, adsorbent minerals that can be deployed to store thermal energy at high temperatures, which can later be recovered when water is added to the mineral. When heat is applied to the zeolite, the process is reversed and the water is released. Hence, zeolites can be used for process heat storage. Indirectly they can be used for electricity storage when being combined with an electricity and heat cogeneration unit for instance.

Table 9 - Chemical energy storage

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	+	days	o	slow	+
France	o	days	o	slow	o
Germany	++	days	o	quick	+
Italy	+	days	o	slow	o
Liechtenstein	+	days	o	slow	+
Slovenia	o	days	o	slow	+
Switzerland	+	days	o	slow	o

6.1.4 Compressed air energy storage

At the moment only two compressed air energy storage plants operate in the world: One in Huntdorf (Germany) and the other one in McIntosh (USA). The Huntdorf plant is located on a 300,000 m3 salt dome, in which compressed air is stored, originally to capture excess nuclear power production. For rapid responses to power shortages, the air is channelled to a conventional gas turbine (290 MW).

Compressed air energy storage (CAES) consists of compressing air with electric compressors (charging) and releasing the compressed air via a turbine (discharging). The discharge can be combined with natural gas or biogas combustion in a turbine. The compressed air replaces air compressed by the turbine itself, thus reducing the amount of gaseous fuel needed for a certain electric power output.

A disadvantage of CAES is the energy loss in form of heat that is generated during the compression without being available for re-expansion if it is not stored. The concept of adiabatic compressed air energy storage (ACAES) includes storage of the heat released by the compressed air in the charging phase and its use for heating up the expanding air in the discharge phase. However, no ACAES systems have been commercialised so far due to cost and heat storage challenges.

A conceptual design study conducted by GE Global Research has shown that ACAES plants in the 100 MW / 600 MWh range can be built with a lead-time of approximately one year from the order. The round-trip efficiency is predicted to reach more than 60 %, the specific investment costs 816-915 €/kW. Incremental energy storage costs are estimated at 23 €/kWh.

Table 10 - Compressed air energy storage

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	+	weeks	o	medium	---
France	---	weeks	o	medium	--
Germany	o	weeks	+	quick	-
Italy	+	weeks	o	medium	o
Liechtenstein	+	weeks	o	medium	o
Slovenia	--	weeks	o	medium	o
Switzerland	+	weeks	o	medium	o

6.1.5 Cryogenic energy storage

A new form of energy storage developed by Highview Power Storage, Leeds, United Kingdom, cryogenic energy storage (CES), is relevant in the context of this assessment, which covers only the German case, because Highview Power Storage has concluded a strategic partnership with Messer Group, Bad Soden, Germany, to commercially explore the CES technology.

In the CES concept electricity is used to liquefy a gas (e.g. air or nitrogen) which can be stored in insulated steel tanks under ambient pressure at low loss rates of about 5 % per 100 days (case of 2,000 tons tanks, corresponding to 200 MWh stored energy; losses are lower if the tanks are larger). The energy stored in liquefied nitrogen is high compared to existing commercial concepts for large energy storage. For discharging, the liquefied air is expanded with ambient or waste heat and drives a set of turbines operating at different pressures and driving an electricity generator. Due to the very low bottom temperature of the cycle, the ideal (Carnot) efficiency of the cycle is very high. If ambient heat is used for the expansion, it reaches 72 %, if waste heat at 100°C is used 80 %. Resultantly, typically 56 % of the waste heat is converted into electricity. If a Ranking cycle is used to convert heat at 100°C into electricity, the Carnot efficiency is only 25 %. The total CES cycle efficiency is predicted to range between 40 % and more than 90 % depending on the exact configuration/temperature of waste heat used.

Table 11 - Cryogenic energy storage

Country	Market availability	Storage period	Storage volume	Response time	Local option
Germany	o	days-weeks	+	quick	-

6.1.6 Pump water storage

Regional water pump storage systems refer to using dams in nearby, higher altitude valleys, to store excess solar or wind power, or to manage and utilise hydropower harnessed from two lakes with different heights or artificial water storages, within the regional context of settlements. Water is pumped using excess or low-priced electricity – the potential gravity energy is maintained with little loss. The stored water is released to drive turbines, to dispatch to meet peak demands.

Table 12 - Pump water storage regional in Alpine Space

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	+++	months	+++	quick	+++
France	+	months	+++	quick	+
Germany	+++	hours	o	quick	--
Italy	+++	days	+++	quick	++
Liechtenstein	+++	months	+++	quick	++
Slovenia	++	days	+	quick	++
Switzerland	o	days	o	quick	++

Table 13 - Pump water storage Scandinavia etc.

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	+	weeks	++	quick	---
France	n/a	weeks	++	quick	n/a
Germany	-	weeks	++	quick	---
Italy	+++	weeks	---	quick	++
Liechtenstein	++	months	+++	quick	
Slovenia					
Switzerland	+	weeks	++	quick	o

6.1.7 Thermal energy storage systems

These storage systems can be combined to every source of thermal heat. Storage materials can be solid or liquid for example concrete, stones, sand, water or combinations with salt. A high variation made it useful to split up the different types of thermal energy storage system. This one is for high temperature – also well know under the term high temperature thermal energy storage systems (HTTESS).

High temperature: The high variation of thermal energy storage options made it useful to split up the different types of thermal energy storage systems. HTTESS is experimented with as an option for storing heat generated from excess electricity in combustion power plants, thus allowing for more flexibly operating base and medium load conventional power plants and biomass power plants. During discharge, the heat is used for pre-heating the combustion air and the fuel demand of the plant is decreased. The saving can be specified by a heat-to-fuel conversion efficiency. In the case of coal power plants, a heat-to-coal conversion efficiency of more than 60 % and an electricity-to-electricity efficiency of more than 30 % were calculated in design studies to be achievable.

Low temperature: Different types of low temperature heat storage can be subdivided into sensible heat storage which goes along with a temperature change of the storage medium, and latent heat storage where heat is stored in a medium that remains at a specific temperature, but changes its physical phase, e.g. from liquid to solid and vice versa. The medium used for sensible heat storage is hot water in most the cases. The range of applications of hot water heat storage is so huge that this option is described separately in the next section. Here, the focus is on latent heat storage whose main advantage compared to sensible heat storage is the lower mass and volume of material required for storing the same amount of energy.

Table 14 - Thermal energy storage system – high temperature

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	+	hours	+	medium	+
France	o	hours	+	medium	o
Germany	o	weeks	++	medium	+++
Italy	+	weeks	+	medium	++
Liechtenstein	+	hours	+	medium	+
Slovenia	o	weeks	++	medium	+++
Switzerland	+	weeks	++	medium	

Table 15 - Thermal energy storage system – low temperature

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	o	week	++	medium	o
France	o	week	++	medium	o
Germany	o	weeks	+	quick	+++
Italy	o	days/weeks	o	medium	o
Liechtenstein	o	days	++	medium	+
Slovenia	+++	days	o		
Switzerland					

The reason behind is that the heat required to change the phase of a material, e.g. from solid to liquid, to say for melting/fusion, is usually much larger than the heat required to raise the temperature of the same material by a certain number of degrees.

The main disadvantage of latent heat storage is that usually one of the phases is solid thus allowing mainly for inefficient heat conduction for heat transfer as opposed to the much more efficient heat convection that is only possible in gases and liquids. This limits the speed at which heat can be stored and retrieved, i.e. the storage power.

Further in latent heat storages, most of the heat can been stored only at a well-defined temperature or within a small temperature range that depends on the material chosen as storage medium. Ice at atmospheric pressure melts exactly at 0°C and ice/water is a suitable phase change material only if the required temperature is about 0°C. If salt is added the melting temperature is lowered to a few degrees minus zero, but it remains very sharp. Hence, possible applications are restricted to very few cases of cooling and freezing.

Paraffin waxes however, melt typically at temperatures between 46°C and 68°C, but the melting interval can be fairly well adjusted to the desired application case. Paraffin waxes can therefore store heat at temperatures that are required for room heating or hot water preparation. As paraffin waxes use to be mixtures of alkanes that melt at different temperatures, the phase change does normally not happen at a sharply defined temperature, but within a temperature interval, thus further broadening the range of possible application cases.

Hot water: A major application of hot water energy storage in the context of matching electricity generation and demand is linked to cogeneration of electricity and heat in combined heat and power plants (CHP). Electricity is not stored, but electricity and heat cogeneration happens in pattern with the electricity demand. Resultantly, this option is rather some sort of electricity generation management. This can be generally said of all cases where electricity and heat are cogenerated in pattern with the electricity demand and the heat is stored.

The CHP can be of very different size, ranging from units supplying single-family houses to units supplying entire city quarters via district heating systems (DHS). Depending on the size of the CHP, the size of the hot water storage ranges from a few cube meters to several 1,000 cube meters. Very large hot water stores can even serve as seasonal heat storage. Thermal storage allows for more flexible operation of CHP, especially to reduce fuel intensive frequent starting processes. Nowadays, hot water storage is generally used to reduce the need for peak load boilers. Existing and recently planned heat storage projects have an installed thermal capacity of 10-40 % of the

Table 16 - Thermal energy storage system – hot water

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	+++	days	+++	quick	+++
France	+++	days	+++	quick	++
Germany	+++	hours/months	++	quick	+++
Italy	+++	days	+++	quick	+++
Liechtenstein	+++	days	+++	quick	+++
Slovenia					
Switzerland					

DHS peak load. The design range is expected to increase to 30-50 % in the future.

Electricity generation-demand matching with hot water energy storage can also be done with heat pumps, which have a sufficiently large heat store. It can further be done with fuel cells, which cogenerate electricity and heat, and it can even be done with simple electric hot water heaters.

Salt: Thermal energy storage systems using salt make use of the energy difference between water bound to hygroscopic salts and water released from these salts upon application of heat. The main advantage is, similar to zeolith, the low energy losses and related suitability as long-term storage medium.

Lithic material: Lithic materials like stones and sand or concrete are used here for the storage. This is an important aspect in concrete core cooling concepts, which are used for managing the temperature in buildings. In the context of electricity generation-demand, matching, lithic materials are used as heat store in HTTESS.

Table 17 - Thermal energy storage system – salt

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	o	weeks	++	medium	o
France	o	weeks	++	medium	o
Germany					
Italy	+	weeks	+	medium	++
Liechtenstein	o	weeks	++	medium	+
Slovenia					
Switzerland					

Table 18 - Thermal energy storage system – lithic material

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	o	hours	o	very slow	o
France	o	hours	o	very slow	o
Germany					
Italy	o	hours	o	very slow	o
Liechtenstein	o	days	o	very slow	+++
Slovenia					
Switzerland					

6.1.8 Flywheels

Flywheels (small-sized)

Flywheels are rotating mechanical devices to store kinetic energy. They releases the energy by applying torque to a mechanical load. Contemporary flywheels consist of a carbon-fibre composite rotor suspended by magnetic bearings. Rotors spin at 20,000 to over 50,000 rpm in a vacuum shell to reduce friction. Such flywheels have nevertheless still high losses of 0.1-10 % per hour.

Flywheels (large sized)

Large-sized flywheels operate on the same principle, but store more energy in a higher mass and physical size.

Table 19 - Flywheels – small sized

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	++	minutes	--	very quick	++
France	o	minutes	--	very quick	+
Germany	o	minutes	--	very quick	+++
Italy	++	minutes	--	very quick	+++
Liechtenstein	+++	minutes	--	very quick	+++
Slovenia	o	minutes	--	very quick	+++
Switzerland	+++	minutes	--	very quick	o

Table 20 - Flywheels – large sized

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	++	minutes	--	very quick	++
France	o	weeks	o	very quick	o
Germany	o	minutes	--	very quick	+++
Italy	--	weeks	--	very quick	o
Liechtenstein	---	weeks	o	very quick	o
Slovenia	--	weeks	o	very quick	o
Switzerland	--	weeks	o	very quick	+

6.1.9 Batteries

Mobile: Vehicle-to-grid (V2G) systems store and dispatch electrical energy stored in networked vehicle batteries which together act as one collective battery fleet for peak shaving and supplementary resource- still largely conceptual.

Electrification of the transport sector is currently considered for several reasons:

- Electric drives are 3-4 times more efficient than combustion engines.
- Electric drives do not produce air pollution at the site of use. If the electricity is provided by renewable energies, air pollution can even be totally avoided.
- Electric drives produce much less noise than combustion engines.
- If the electrical energy is provided by onboard batteries, the latter can store and dispatch electrical energy to the grid (vehicle-to-grid systems, V2G). The networked vehicle batteries can work together and act as one collective battery fleet for matching electricity generation and demand.

Batteries for vehicles must be light-weight and must have a high energy storage capacity which allows driving the vehicle over a sufficiently large distance. For this reason, essentially lithium-ion batteries are considered as candidates for mobile batteries. They must further be safe under normal operation as well as in case of a traffic accident. This limits the choice of suitable batteries further to some kinds of lithium-ion batteries, which are proven sufficiently risk-free.

Key questions as to the usability of mobile batteries are:

- How many mobiles will exist?
- How often and when will they be hooked to the grid?
- Will it be possible to implement a bidirectional energy flow?

Stationary batteries: Contrary to mobile batteries, stationary batteries do not necessarily need to be light-weight. Their volume is more important. The safety requirements are also lower. For example, it is not necessary that the battery can be turned upside down without causing damages, thus allowing also the use of lead-acid batteries more easily. Examples of stationary batteries include lead acid batteries, lithium ion batteries, (vanadium) redox-flow batteries or hybrid-flow batteries.

Lithium-ion batteries: About 30 manufacturers of lithium-ion battery cells exist worldwide. Improvements of lithium-ion batteries are made at all levels. The extrapolated remaining capacity of Sol-ion (lithium-ion) batteries after 20 years is 80 %. Cycling accounts for about 2/3 of the capacity reduction calendric aging for about 1/3. Used lithium-ion batteries from vehicles can be reused as stationary batteries when they have no longer a sufficient capacity for mobile application.

Table 21 - Mobile batteries

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	--	hours	-	very quick	+++
France	+++	hours	-	very quick	+++
Germany	+	hours	-	very quick	+++
Italy	++	hours	o	very quick	+++
Liechtenstein	o	hours	-	very quick	+++
Slovenia	--	hours	-	very quick	+++
Switzerland	--	hours	-	very quick	+++

Lead-acid batteries: Lead-acid batteries have been used as stores in RE systems for more about three decades and can be considered as established, proven and relatively cheap battery storage technology. The main disadvantage of lead-acid batteries is their high weight.

Vanadium redox-flow batteries: Vanadium redox-flow batteries are the most common example of redox-flow batteries being used. Their energy storage capacity can be designed independently of the power capacity. While the former depends on the amount of electrolyte, the latter is determined by the size of the ion exchange membrane etc. Current production vanadium redox batteries achieve an energy density of about 25 Wh/kg of electrolyte. The energy is stored in the electrolyte and discharge losses are minimal.

Table 22 - Stationary batteries

Country	Market availability	Storage period	Storage volume	Response time	Local option
Austria	o	days	-	very quick	+++
France	+++	days	-	very quick	+++
Germany	+++	hours	o	very quick	+++
Italy	+++	days	o	very quick	+++
Liechtenstein	o	days	-	very quick	+++
Slovenia	o	days	-	very quick	+++
Switzerland	o	days	-	very quick	+++

6.2 Comparison of storage and alternative options

6.2.1 Generation management

Generation management is the usual way to deal with the fluctuating electricity demand. Depending on the technology, generation management can be more or less easily implemented. In the conventional electricity supply system, generation management is cascaded and a distinction is made between continuously running plants (base load plants), plants more or less continuously running for several hours (medium load plants) and plants whose power output is quickly changed within a few minutes (peak load plants). Below the scale of a few minutes, generation management is complemented by short-term storage in the conventional electricity supply system, essentially by spinning reserve of large power plants.

The power output of nuclear and lignite power plants, and run-of-the-river hydropower plants cannot be easily varied. Such plants use to be operated at constant power and are classified as base load power plants. Hard coal and oil power plants are classified as medium load power plants, and gas power plants and hydro storage power plants as peak load plants.

Contrary to most conventional power plants, the output of most RE power plants can be easily varied. The most difficult is the regulation of the power output of biomass combustion plants which contribute only a minor part of the RE electricity supply. They are comparable with hard coal power plants and can be classified as medium load plants. All other renewable energy plants can be regulated within a few seconds or minutes and are therefore similar to conventional peak load power plants.

The output of geothermal power plants can be varied by modifying the pumping rate for the hydrothermal water or the injected water. Biogas plants can be controlled in the same way as gas power plants at least for short periods. If the power output is strongly fluctuating, provisions must be provided for intermediate storage of the produced biogas. Hence, all these plants are peak load plants. They are nevertheless operated essentially as base load plants in Germany in order to ensure a better profitability.

In the case of the fluctuating RE, wind and solar PV, the regulation of the power output is extremely easy and can be done within seconds or microseconds, i.e. even more quickly than in the case of gas power plants. However, the limitation of the power output is usually avoided because the marginal costs of the electricity generated in wind and PV power plants are zero. Generation management is nevertheless applied in order to deal with grid bottlenecks and it can be seen as an alternative to electricity storage or grid extension and reinforcement.

6.2.2 Demand Side Management

Demand Side Management (DSM) denotes measures serving to modify the final energy consumption. The overarching aim of DSM-measures is to even out the residual load curve, i. e. the power demand that cannot be provided by renewable energies. The adopted measures can facilitate new options to control energy in order to stabilize the grid, to smooth the daily load curves to enable a steady capacity utilization in power plants – conventional and virtual alike -, and to reduce the peak load to lower capacity credit in general. DSM generally helps to make electricity consumption, and therefore the whole energy system, more flexible and can serve as a transition-tool adopting consumption to fluctuating, renewable generation in particular. In practice, Demand Side Management can apply several instruments that each aim at different, discrete targets for the energy consumption – mainly reduction in energy use and shift of consumption.

One target is to achieve energy saving in general. Feedback-instruments provide the customers with information on their consumption in a particular week or month, at different days or times of the day and can even provide real-time information on consumption. In some cases, using "submeter" data is not only available for the entire household but also for individual appliances. In fact, the consumers are equipped with the necessary information to detect "power guzzlers" and are thereby enabled to develop a general awareness for energy consumption that leads them to save electricity.

Feedback instruments come in a variety of forms: They can be an App for a smartphone or a tablet-PC, they can be a display, distinct from other devices or incorporated into an energy management gateway. Feedback can also be provided via an internet platform, but it may also just be a detailed, monthly bill. In any case, displays, apps and internet platforms offer more information and better visualization options than bills.

Feedback-instruments can also render information on e.g. the share of renewable energies being produced in the region or on real-time prices for electricity. For example, when a high price for energy is set during a time with a load peak and the customer is informed, the feedback instruments serve to incentivize load shifts on a daily basis or at critical times. Apart from feedback with manual adaption of consumption, DSM can be implemented via automated control devices together with variable tariffs.

This leads to a differentiation of central and local load management strategies:

- Demand Side Management (DSM) with price signals relies on decentralised, manual or automated decisions. Central load management detects control needs, generates respective price signals and sends them to the energy user, who then individually reacts to the incentive. Of course, the customer can be a source of unreliability, as

the incentive might not be strong enough to lead him to adjust his energy consumption or he simply refuses to reflect his energy consumption in general.
• In the case of Demand Control (DC), the decision is centralised with an operator who can send direct control signals to a specific pool of appliances to switch them on and off. The incentive for the owner could be a fixed remuneration for the availability of his appliances for such interventions.

6.2.3 Grid expansion and reinforcement

Mostly the addition of renewable generation capacity takes place in the distribution grid and often at medium voltage and low voltage level, especially with decentralised wind power and photovoltaic systems. Issues of voltage stability, the ratio of active and reactive power and the occurrence of revered load flows from distribution to upstream grid levels are enormous challenges for the grid and their operators.

Grid extension and reinforcement are presently the main measures to deal with this changing needs and go along with the switch towards a fully RE-based electricity supply system. Storage technologies and alternative ways can diminish grid expansion but not completely prevent. EU-wide frameworks support the optimisation of the grid infrastructure and the expansion of the renewable energies. These frameworks push the expansion of the European internal market and the cross-border electricity trade. Similarly, these frameworks are important factors for the environment and climate protection.

The energy strategy “Energy 2020” (2010) and the “Energy Roadmap 2050” (2011) provide the direction of the energy policy in Europe. Specifically, the following fields should be promoted:

• the emergence of additional supply and transmission routes,
• the simplification and acceleration of authorisation procedures
• the improvement of renewable energy sources,
• the development of fair competition within the EU,
• the intelligent/smart connection between all European national grids,
• and to ensure the security of energy supply and consumer protection.

These objectives can be reached by a modernised and innovated configuration of the grids. For this reason, the European Commission has submitted the energy infrastructure package in October 2011. It includes concrete funding measures and rules for the expansion of the regional and transnational energy grids. Therefore, in this case, the acceleration of authorisation procedures has high priority.

Considering the growth of the European energy market, the cooperation of the European Transmission System Operators (TSOs) and the European regulators is of major importance. In 2011, the association of European TSOs ENTSO-E started its work. The ENTSO-E has the task to develop and to publish a unified grid development plan every two years. Within this plan, the requirements for grid expansion are calculated for a period of ten years. Major points are the expansion of cross-border transmission lines and removing bottlenecks in the transmission grid.

Since June 2013, the regulation on guidelines for European energy infrastructure (TEN-E-act) aims for achieving the EU energy policy objectives for a functioning internal energy market and security of supply. At the same time, the development of the renewable energies should be promoted. The effective and accelerated grid expansion is an opportunity to achieve these goals. In terms of grid expansion, four trans-European electricity corridors have been created:

• Northern seas offshore grid (NSOG),
• North-South electricity interconnections in Western Europe (NSI West Electricity),
• North-South electricity interconnections in central Eastern and South Eastern Europe (NSI East Electricity),
• Baltic energy market interconnection plan in electricity (BEMIP Electricity).

The TEN-E-act specifies how projects with mutual interest were identified and defined. The criteria are the economic, social and ecological use of the projects as well as transnational impact of the projects on at least two member states.

The member states, regulation authorities, TSOs and promoter acquire and asses the proposals for the projects in regional groups, chaired by the European Commission. After taking into account the opinion of the agency for the cooperation of energy regulators (ACER), the member states and the European Commission will resolve the lists of "project of common interests" (PCI) as a decision-making body. Subsequently, these lists are merged into a comprehensive Union-wide list. Finally, the European Commission issues the PCI-list as a delegated legal act.

6.2.4 Comparison of storage and other options

At this stage, only first results of modelling the existing and potential future electricity supply system can be discussed. Only few models investigate the whole range of options for matching electricity generation and demand in place and time, the whole spectrum of generation and storage technologies, and the existing grid.

For instance, a multi-criteria analysis has been performed by the Wuppertal Institute for Climate Environment and Energy to identify the most appropriate alternative solutions to limiting wind power generation in case of lacking electric grid capacity. Economic, ecologic, political/ social and technological criteria have been considered and different weighting sets were applied to test the robustness of the results. The outcome is that, within the time-horizon of 2020, dynamic thermal rating of overhead transmission lines, additional DC underground cables and adiabatic CAES are the most suitable options to deal with excess power production from wind energy converters. Storage technologies, except adiabatic CAES, are considered less suitable than limiting the wind power generation.

From the assessment of storage technologies given above, it becomes clear that the multi-criteria analysis is far from being complete. Notably, the role attributed to CAES surprises if one reminds that only two plants exist worldwide at the moment. The potential role of more flexible biogas plants, hydrogen and SNG, cryogenic storage, electric demand-driven CHP, DSM etc. however is not sufficiently reflected.

At local level, the integration of PV plants in the low voltage distribution grid is increasingly gaining importance. The main solution discussed for better integrating a very high PV generation power in the low voltage grid are battery stores.

The effect of equipping decentralised PV systems with battery stores has been evaluated in a study conducted by the Fraunhofer-Institut für Solare Energiesysteme (FhG-ISE) in Freiburg for a low-voltage rural and a suburban grid. The study distinguishes conventional and grid-optimised storage operation. In the former mode the battery is charged whenever available electricity is not used and the battery is not fully charged. In the latter mode which is the object of the investigations made in the study, the battery is charged and discharged such that the electric grid is efficiently stabilised.

6.2.5 The integration of sustainable mobility, energy storage systems and intelligent grids

<u>Vehicle to Grid (V2G)</u>: Vehicle to Grid (V2G) means that electric vehicles are used for energy storage in a smart grid. In this concept, the battery of an e-car is charged when the price is low (for example at night) or an overproduction of electricity takes place (e. g. at high noon from PV). In contrast, the energy from the batteries is fed back into the grid, when the price for electricity is high or the offer of electrical energy cannot satisfy the demand.

In this way, owners of electric cars can gain money benefit resulting from price difference of electric power. With an intelligent control system, the e-cars, which are connected to the grid, could decide when and to which level the battery has to be loaded. This calculation can be based on how far their owner are going to drive today and what the battery would therefore require. Thus, the problem of simultaneous charging of many car batteries at the same time could be avoided.

Electric cars are only truly sustainable if the energy for charging comes from RES, such as wind or solar. For example, a wind turbine with three MW peak power can charge about 830 one phased electric vehicles (3,000 kW / 3.6 kW) or about 135 three phased electric vehicles (3,000 kW / 22 kW). The electric vehicles can also be used as storage for the produced energy. This type of mobile storage offers two advantages: The power supply utilities would have a buffer against excess energy from RES – assuming the batteries can handle the frequent loading and unloading. Being remunerated for their flexibility, the vehicle owners would have an opportunity to finance the relatively expensive batteries.

Smart Charging – intelligent V2G-communication: Uncontrolled charging can quickly lead to a number of problems for the user of an e-car and the power grid. For example, the immediate charging of a heated up battery under full load can affect the durability of the battery. The different types of charging modes are shown in Table 23. As noted above, if several e-cars are being loaded at the same time in the same local grid, this grid may soon reach its limits. Furthermore, usually the conventional charging at a public charging station does not provide (now a days) a way for automatically billed charging. Due to all these disadvantages automobile manufactures, manufactures of charging stations and grid operators work on concepts for "Smart Charging", where the charging station communicates with the charging control device of the electric vehicle.

Maintaining grid stability is one of the main reasons for intelligent charging. Field studies have shown that customers often charge their e-cars at the end of their working day. At these times, power grids are stressed anyway. The risk of overloading local grids can be easily avoided by controlled charging. In most application scenarios, it is not necessary to charge the e-car immediately with maximum power. Often the charging process can be distributed over the whole night. If future smart grids with dynamic electricity prices become reality, even a shift of charging to periods of low electricity prices (e. g. temporarily over-production by wind power) is conceivable.

The basic requirement for smart charging is a communication link between the car and the charging station. Therefore, a bidirectional communication is important. Neither grid nor car can control the charging process. Only through a "negotiation" of the optimum parameters, the optimal charging curve can be calculated.

In Europe, a group of experts is currently working on the ISO/IEC 15118 standard to unify "Smart Charging". In this standardisation, there are all major actors represented, such as energy providers or components manufactures. The ISO/IEC 15118 standard is made up of

Table 23 - Different types of charging modes

	voltage	power	performance	charging time 20 kWh	port	private/ public
mode 1	230 V/ 1 phase	16 A	3,6 kW	3,8 h	Schuko-socket-outlet	private
mode 2	400 V/ 3 phases	32 A	22 kW	0,6 h	CEE-socket-outlet	private
mode 3	400 V/ 3 phases	63 A	44 kW	0,3 h	securely connected	private/ public
mode 4	400 V DC	150 A	60 kW	0,2 h	securely connected	public

three parts and defines the functions for the communication of the various layers according to the OSI-model.

Part 1 deals with the application, part 2 deals with the layers 3-7 and describes the technical protocols. Part 3 deals with the physical and connection requests to the bit transmission layer and data link layer (DLL). The ISO/IEC 15118 standard describes aspects the active charge control, power input and the spontaneous adjustment of the charging process to avoid overloading of the grid. ISO/IEC 15118 promotes the power-line communication (PLC). Another important point is that the protocol also works for DC-charging. This avoids the need to foresee two connectors for AC and DC-charging.

As a long-term goal, the support for inductive charging is defined in ISO/IEC 15118. The protocol layers are designed so that they can be used on many transmission means. In this context, a significant advantage on the vehicle side is that only one protocol must be implemented. With an increasing spread, the “Smart Charging” concept is necessary to integrate electric vehicles into the grid in a sustainable way.

It also offers the customers added value by performing the charging process reliably and safe. After all, it is necessary to structure the public charging configuration as customer-friendly as possible. The international standard ISO/IEC 15118 unifies the used technologies, so that the user finds the same comfort at least at any European charging station in the future.

7. Socio-economic requirements and user acceptance

7.1 Groups of stakeholders

For the research of acceptance, it is very important to detect the public perception of a technology. Therefore, different stakeholder groups must be considered as multipliers, especially if behavioural aspects should be analysed.

In the following, different kinds of stakeholder groups will be explained in more detail. This categorisation is based on the study "social acceptance of Carbon Capture and Storage (CSS) on national and transnational level", conducted by the Wuppertal institute, research centre Jülich (STE), Fraunhofer institute (ISI) and BSR Sustainability GmbH (Cremer , et al., 2008).

- Politics: Policy actors are relevant as concrete decision makers. Politics provide the framework conditions for the promotion of ESS and decide in what framework (climate policy programme) energy storage systems are used.

- Economy: Actors in the economy connect business interests with energy storage systems (ESS). According to that, the actors arrange their position on the issue. After all, these parties have to build the ESS and eventually to operate them. Therefore, actors in the economy are central actors for the public.

- Civil society:
  - Non-governmental organisations (especially environmental associations), religion groups, trade unions, other organisations (e. g. consumers association). Such organisations are key multipliers.
  - Individuals, supporters of the public opinion.

- Research & Science: Universities, research institutions, training organisations and expert councils. The actors of these groups significantly influence the forming of an opinion. Thereby, they benefit from the (possible) increased activities in the topic area through public and private research funding.

- Media: The public opinion is centrally determined by consumption (and their treatment) from information in the various media. In this respect, journalists are key actors, too.

7.2 Criteria for acceptance of energy technologies

Commonly used methods for the measurement of acceptance are various forms of surveys. Furthermore, there are experiments, studies, media analyses, observations and explanations of different stakeholders. Hence, lessons learned can already be drawn from other areas of technology. The hereafter-listed criteria must be observed in this context since they have an essential effect on the attractiveness of energy technologies.

- Risk perception – probability of occurrence and level of damage: The acceptance of (new) technologies depends very much on the risk perception of the individual. The systematic assessment of risk perception depends on defined criteria in the research of acceptance. These are, for example, publicity, insecurity, controllability, impact on future generations or trust in institutions.

- Regionalism: The regional spreading of costs and benefits can be very important for energy technologies. On the one hand, there could be a possible concentration of plants and technologies. This concentration can lead to transgression of financial "thresholds". On the other hand, regional differences can occur, if the benefit is not proportional to the costs. This could be the case if the technology includes residues with negative characteristics.

• Centralisation – Decentralisation: Technologies with a strong central character can develop a different "profile" than technologies with a strong decentralised character. In case of centralised technologies (usually large-scale technologies), it is easier for the operator to compensate neighbours to accept the existence of the plants. This is less the case for decentralised technologies. However, for an opposition that is motivated from the perceived threat of global goods it is less easy to focus on centralised technology-projects. Therefore, there will always be pros and cons about centralisation and decentralisation.

• Impact on future generations: Risk impact on future generations is acceptable, if the chances of future generations are at least as large as the needs of the present generation. Moreover, the future generations should not be negatively affected by actions of the current generation (compromise their progress).

• Indirect effects of technology: Indirect effects of technology can be positive or negative. For example, if a technology creates new jobs, the acceptance of this technology will increase. However, if the technology causes reduction of employment, the opposite will happen. Similarly, the possibility of technological leadership and the associated export prospects for a country are also indirect effects. The dual use of a technology belongs to this category as well. However, every coin has two sides, meaning, that indirect effects of technology can also include abuse (e. g. production of weapons).

• Competitive economic benefit: The acceptance of a new technology or an individual technical system depends on its impact on existing or potential future economic activities. If such activities are compromised or a threat is possible, it can lead to an opposition against planned projects. Basically, potential economic losses can be compensated monetarily. To this end, an agreement must be found to the existing influences and how these influences should be evaluated. It is even more difficult to negotiate compensation if a competing economic benefit occurs only by malfunction. In this case, additional possibilities have to be evaluated.

• Competitive goods: Competitive goods are the environment, the nature in the sense of conservation, the landscape as an aesthetic unity, human health or monuments. Partially, legislation requires compensation if official legitimate goods are claimed for example compensation areas for wildlife sanctuaries affected by the technology. The relationship between technologies and such goods can strongly affect the acceptance. The protection of such competing goods is often supported (but not exclusively) from NGO's such as environmental organisations. Meanwhile, these organisations have reached a high level of professionalism and competence.

8. Integration of AlpStore models with the AlpEnergy VPS model

8.1 The VPS model as defined by the AlpEnergy project

In the years 2008 to 2011, partners in France, Germany, Italy, Slovenia and Switzerland co-operated in the project "AlpEnergy - Virtual Power Systems as an Instrument to Promote Transnational Cooperation and Sustainable Energy Supply in the Alpine Space" under the European Territorial Cooperation Programme "Alpine Space" (ETC-ASP) 2007-2013.

The Virtual Power System (VPS) model aims to create solutions to the problems through the management and control of the local energy balance of both power generation – the Virtual Power Plant (VPP) and the demand side – Virtual Load Plant (VLP). The VPP made by many different RES power plants. The VLP made by the local energy market of private homes, enterprises and public facilities. Storage systems, smart meters and energy manager systems have a strategic role to allow the operation of the VPS. In AlpEnergy, a VPS is defined as a system that integrates, manages and controls distributed energy generators and storage capacities and links their technical operation to the demand of consumers and the energy market.

A VPS links and balances generation and consumption of power in a defined subset of the entire (smart) grid. The spatial extension of a VPS may vary from very small settlements to entire countries. The elements forming a VPS

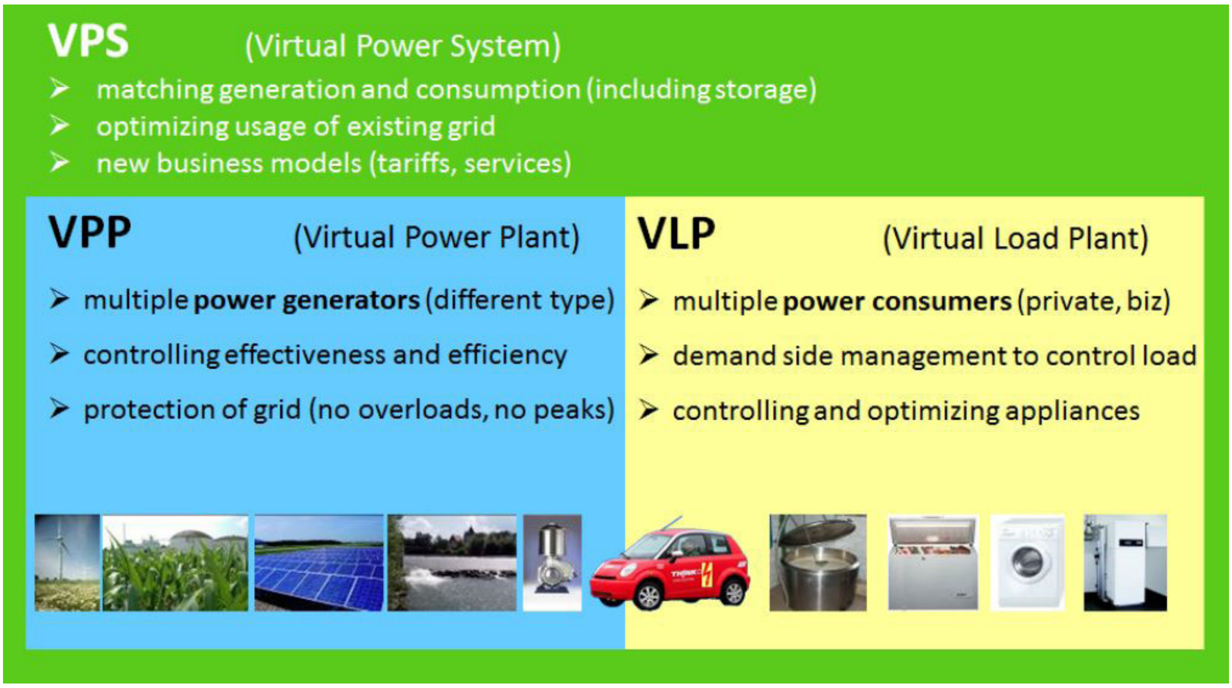

Figure 12 - Concept of a Virtual Power System (Ludwig Karg, 2011)

can be concentrated in one zone or spread over a larger area, they can determine the whole electricity supply and consumption of an entire zone or only the electricity generation in, and consumption of, a few facilities within an area.

Electric vehicles will play a role in the future energy system; their batteries and charging stations may or may not belong to a VPS. In any case, they have a hybrid role: being a power consumer, their load process can be controlled to balance availability of volatile sources, being an energy provider, they can feed energy from their batteries into the grid when needed.

The VPS may include energy storage units for improving its performance with regard to synchronizing electricity generation and consumption. Storage units in the usual sense convert electricity after it has been generated/transformed into another form of energy (chemical, rotational, pressure, etc.), store the energy in that other form, and reconvert it into electrical energy. Two other forms of storage options can be identified along the energy conversion and use chain:

- Storage of energy before conversion into electricity, e.g. in the form of biomass or water in Barrages;
- Storage of energy service (e. g. heat generated by heat pumps, cold generated by cooling devices, energy in PHEV batteries read to drive a vehicle) after provision by electricity.

8.2 The AlpStore concept

The introduction of energy storage systems (ESS) into the electric grid aims to better control the variations of instantaneous power load, as it allows to smooth power peaks typical of stochastic users and producers. This approach brings three main advantages for the electric energy system: the increase of the system efficiency (i.e. energy saving), the increase of potential installed power for RES plants, and a steadier and reliable management of the electric energy. However, the introduction of ESS needs to be evaluated and designed, according to the framework in which they are planned and implemented.

In recent years, the European countries and the Alpine Space regions have been characterised by a large increase of distributed power production from RES. Therefore, the electricity grid is, in many cases, subject to critical working conditions.

Some constraints of the electricity network are due to its physical features such as: the cable size, the mesh of the grid, the distance between the areas of energy production and consumption etc... For instance, in Italy, the distributed power generation often involves the transmission of the electric power from the peripheral areas of the grid, which often lack of a correct sizing of the cables.

Energy production from RES is mainly not programmable, and is characterised by high installed power values compared to the average amount of energy produced in one year. This means that the grid has to cope with inlet power peaks that may occur when the energy demand is low. In these situations, in order to ensure the security of the grid and balance power demand and offer, it is often necessary to limit the input of electric power from large programmable power plants. Consequently, a certain number of plants ready to assure their power input to the grid in few minutes are required.

As a result, the installation of new renewable plants in many areas has been constrained, as they would constitute new elements of disturb. Winding up the national and local electric power system presents today some criticalities such as:

- overloaded portions of the grid;
- difficulty of accepting new installations of plants exploiting renewable sources;
- need for conventional plants always in idle.

The penetration of ESS in the energy system represents a potential solution. An effective implementation and management of ESS requires intelligent nodes constituted by “smart devices” interacting with the users, the stochastic energy source and the grid storage system. EV’s can be seen as a form of mobile storage and sustainable mobility. With a correct management system EV’s can play an important role in balancing energy supply and demand.

In this context ICT plays a critical role. Through a proper ICT structure, the nodes (smart devices) will communicate with each other and with a central control unit; the latter will be able to interact with the nodes modifying the operational parameters of each of them if necessary. The electricity grid, originally designed as a distribution grid, must become an interactive grid, needing to be integrated by a parallel communication network for the management and the real-time elaboration of information.

8.3 The integration of RES, ICT management, storage and mobility in a local perspective

The AlpEnergy model and AlpStore concepts are strictly connected. The AlpEnergy model needs storages to increase the level of control of the VPS, and has as target local users which represent the virtual load side. In AlpStore the focus of the studies is specifically on various storage technologies and their possible applications with RES plants and, consequently, in a VPS. It also explores the connection between RES power and local sustainable mobility: the VPS could be the management answer.

The AlpStore partners that have also taken part in the AlpEnergy project are developing a pilot activity in their respective regions. They describe their project idea of integration of the two models, considering their technological and economical requirements, goals, opportunities and constrains.

Biogas, electricity, hydrogen are at the same time fuels for sustainable vehicles and energy carrier that can be stored with appropriate equipment, on board of many vehicles or in stationary storages, located near the RES plants, or near the charging stations, or in a different place connected by VPS and its communication system.

In a local perspective the implementation of ESS has to be planned according to the characteristics of the energy production and consumption system, the transmission and distribution grid, the local energy policy and the territory. Within the Alpine Space regions these characteristics may broadly drift apart from the national ones.

Using a bottom-up approach the role of ESS might be double. A first objective regards small energy users and producers aimed to decrease power load peaks while maintaining the same energy consumption level. In this case, small size storage systems can be considered. These storage systems, sized on the basis of the single users, will have a sufficient capacity to smooth the load diagram with time constants of some hours. The storage may be provided both for one-way users (consumers) and for two-way users (prosumer).

A second objective may be defined at a larger scale (e.g. regional scale, MV level) and it should be aimed at managing the energetic dynamics of a part of the territory by operating directly to MV and HV production level. The Alpine regions are often characterised by the large presence of renewable power production (e.g. owing to the presence of hydro-electrical basins). In these cases, the energy storages need to be sized on a larger scale, both in terms of capacity and of time constants. However, the advantages would be the same as the previous point. The presence of small-distributed storage systems (LV) is strategic also in view of the second objective, as allows smoothing the loads and making the demand diagram more homogeneous for one portion of the territory.

Electric Vehicles can be thought as mobile ESS that are exploited, in addition to the stationary storages, to smooth the electric load diagram.

In this case the nodes of the network are constituted in large part by the connection stations for the electric vehicles batteries loading, which can be either connected to a public network or to private households. An example initiative that may be applied locally involves the construction of a demonstration mini-park of zero-emission vehicles for light transport.

The network will therefore be subjected to more homogeneous energy demand and the interaction among the low voltage and lower power values and lower power rises and drops will characterise high voltage nodes. The medium voltage grid, at its turn, will interact with the high voltage in a less disturbed dynamic.

Finally, on a local scale, the advantages (bottom-up approach) are:

- The increase of the amount of renewable energy (stochastic source) that can by hosted by the energy system.
- The lightening of the network LV, MV and eventually HV grid load.
- Increase of local RES self-consumption.
- The achievement of local energy and environmental targets.
- The implementation of specific initiatives and tools on the territory that pursue the policy targets.

The evaluation of the main effects generated by a massive penetration of storage units in the local energy system may be assessed by the aid of simulation engineering. The numerical simulation and the possible experimental tests will determine the strengths and weaknesses in energetic and economical terms of the various technologies tested.

Because of the peculiarity of ESS any initiative and measure locally planned and implemented should be strongly based on the characteristics of the local context and designed according to the results of consistent numerical simulations.

9. The STORM concept

9.1 The purpose of STORM

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.

In general terms, STORM follows the approach of Strategic Energy Action Plans (SEAP) on regional level. While a SEAP very often describes overall generation and consumption of a region in the future, STORM takes the regional energy transition process to more detail. Especially when it comes to intermittent generation the entire energy system needs better balancing using short term and long term buffers. Operating a power grid may become too expensive if huge power flows need to be transferred to and from the transmission grids. It may be cheaper to balance on a regional level using the right storage technologies and IT based control systems.

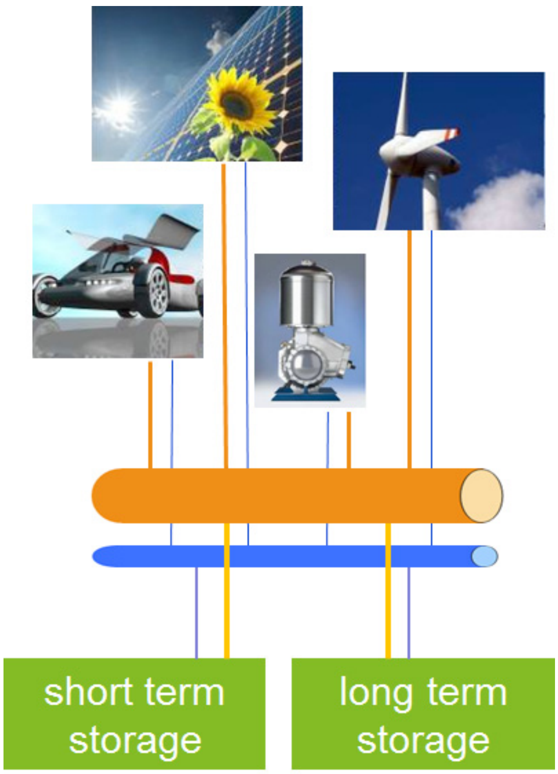

Figure 13 - Linking Generation and Storage with copper grids and communication networks, source: (B.A.U.M., 2013)

While a SEAP typically shows to what degree regional supply can be achieved, STORM wants to help implement such long term plans in practical terms. As rule of thumb following principles seem to be appropriate:

- Connect RES to the power grid wherever the grid is strong enough to cope with the extra power feed-in
- Implement it systems to control generation and consumption as possible using methods of demand side management (DSM) and generation side management
- Connect short term and long term storages to the grid as needed and control them via Information and Communication Technology (ICT).

To that end, STORM addresses the stakeholder group that has developed a regional energy master plan and then wants to take responsibility for its implementation exploiting storage systems at their best. Such stakeholders are:

- Local and regional power suppliers and grid operators
- Planning departments in local and regional administrations
- Technology firms and regional crafts that supply storage technology
- Scientific institutes supporting the practitioners
- Media that have a relevant influence on the discussion and decision processes.

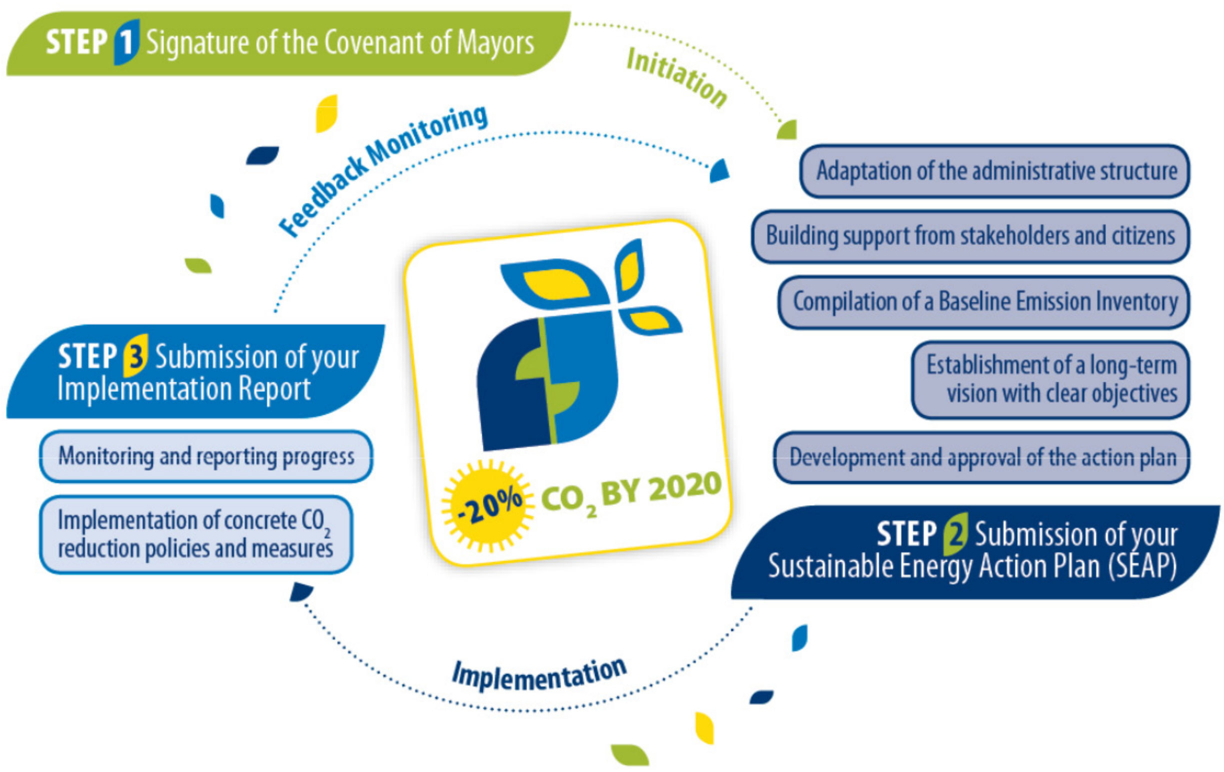

Figure 14 - The Continuous Improvement Process of SEAP (Covenant of Mayors)

9.2 STORM Workflow

As stated above, STORM relies on the results of a regional SEAP and takes them further. While a detailed description will be given in the final guidelines (that will be published by Alp-Store in early 2015) the general workflow comprises for steps:

1. Investigation of future regional generation and consumption patterns

This task will normally have been accomplished by developing a 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. To allow for the development of practical supply systems, consumption should be described with its development over the day, including potential flexibility. The same is true for the generation side. If any possible in this first step various options should be described that allow for building am optimal regional "farm of generators".

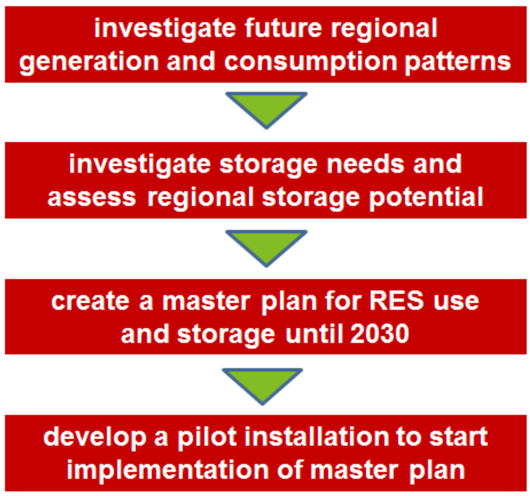

Figure 15 - The STORM step-by-step approach to a holistic regional energy transition

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.

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. Mainly in electrical power systems it is the limitations in the flexibility of consumption that pose the need to either transfer energy through transmission grids and / or store it for later times. While with low penetration of grids with fluctuating generation (below 40 %) in most cases means of generation and demand side control will sufficient to maintain stability of the system, with higher penetration the need for storage will quickly increase.

As described in chapter 6, 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 bit also the potentials of local implementation of such systems. As 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. The AlpStore final documents will contain guidelines to assess the regional storage potentials and the benefits of using them.

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 hint 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 (SMP). They can service as blue prints for similar regions and a source for ideas for all others.

4. Implementation of the master plan by pilot installations

While the SMP is a long term strategic plan, practically the region needs an implementation plan at least for the first steps. Such implementation plans should cover specific projects and describe the pilot installation process in detail including elements for the evaluation of costs and benefits. AlpStore partners developed such plans and have chosen the following structure

Figure 16, Climbing a mountain always starts with the first step (source: David Ionut/Shutterstock.com)

to describe their pilot implementations:

- The pilot region
- Choosing the locations for the pilot implementation
- The implementation team
- Planned activities (technology, step by step work plan)
- Impact of the implementation: expected results, regional relevance and value added, degree of innovation)
- Accompanying communication concept
- Monitoring concept to assess success

From experience one can tell that developing a storage master plan and such comprehensive implementation plans can take quite some time. 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 chap. 9.3). Many of such measure have been proven feasible in the pilot implementations of the AlpStore partners

9.3 Short-term non-regret options for players in Alpine regions

While the STORM concept addresses middle and long-term aspects as well, the following chapters describe short-term "non-regret" measures that key players in the Alpine Space can take.

9.3.1 Recommendations for Local and Regional Authorities

- Go ahead and invest in renewable energies and energy saving in own buildings and facilities.
- Provide guidance to the regional development by establishing jointly with interested citizens and relevant regional players an integrated regional energy development plan based on a thorough assessment of local/ regional renewable energy generation, energy saving, DSM and storage options.
- Ideally, let calculate a research institute which variants of the regional energy development plan have which costs and benefits by using a detailed regional model of energy supply and demand.
- Employ an energy change manager for managing the transition to a mainly RE-based energy supply and for consultation of citizens and companies.
- Motivate citizens and companies to invest in the energetic refurbishment of buildings and the use of renewable energies for hot water preparation, heating, and cooling.
- Set up local/regional support programmes for storage technology, e. g. for battery stores in PV plants.

9.3.2 Recommendations for Regional Energy Utilities

- Invest yourself in RE electricity generation, including PV plants on rented roofs of citizens, companies and public buildings. This will allow you "keeping a hand on things" even if the electricity generation becomes much more decentralised than today. Owning generation plants will allow you more easily monitoring dispersed generation, optimising grid extension, storage, generation measurement, etc., and better designing suitable variable tariffs, e.g. for stimulating DSM.
- Optimise the installation of new generation facilities in pattern with the grid extension.
- Invest in pilot storage facilities to manage local grid bottlenecks and to gain experience with different storage technologies.
- Bundle electricity generation and DSM and operate on the electricity markets.

9.3.3 Recommendations for Investors

• Continue installing renewable electricity generation facilities of all kinds and do not wait for better storage systems. In most cases, the electric grid is able to accommodate an even much larger share of RE electricity than it does at present or it might do so after minor extension or reinforcement.
• If you plan to install larger RE electricity generation facilities such as a large wind park, investigate the option of a connection to the medium-voltage distribution grid or even to the high-voltage transmission grid via a separate generation grid installed in parallel to the existing distribution grid.
• Equipping PV systems with battery stores might be an interesting option if this increases the self-consumption rate of the generated PV electricity and avoids electricity purchase from a power supplier. This might notably be the case for small commercial users with a pronounced demand peak during daytime.
• Complement large new biogas plants with up-grading facilities wherever it is possible to inject bio-methane into a nearby gas line.
• If you combine a biogas plant with strong intermittent RE electricity generation facilities such as a large wind park, investigate the option of converting a part of the generated electricity to SNG. This can be done in a P2G unit that converts the carbon-dioxide fraction of the biogas into bio-methane, thus replacing the gas-washing unit that is usually installed for up-grading biogas to bio-methane.
• Complement existing biogas plants with further CHP and extended biogas storage tanks, operate the plants in a flexible mode, and sell the electricity via an accredited seller on the spot and balancing energy market instead of making use of the guaranteed remuneration.
• Try to negotiate a financial compensation from the local distribution grid operator if your investments avoid him extending or reinforcing the electric grid.
• Try to sell your RE electricity to a green power supplier who might be interested in buying RE electricity in pattern with a fixed time-plan which you might guarantee thanks to your storage facilities.

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