UNIT V

Forecast of EES market potential by 2030

As mentioned in section 3, there are many applications for EES. For some applications EES has already been commercially deployed and it will continue to be used for these applications in the future. Furthermore, some new applications for EES are emerging, such as support for the expansion of renewable energy generation and the smart grid. The importance of EES in the society of the future is widely recognized, and some studies on the future market potential for EES have already been carried out. While these studies vary in target time range, target area, applications considered and so on, they can be classified into two categories: estimates of the future market covering almost all the applications of EES, and estimates of the future market focusing on specific new EES applications. In this section some studies' results are shown for these two categories.

5.1EES market potential for overall applications

In this section two examples of studies and one specialized simulation are presented: a study from Sandia National Laboratory (USA) which evaluates EES benefits and maximum market potential for almost all applications in the USA; a study prepared by the Boston Consulting Group which forecasts the cost reductions in EES technologies and estimates the profitability of investments in EES by application, so as to judge the world market potential; and a simulation of the future Li-ion market by Panasonic.

5.2EES market estimation by Sandia National Laboratory (SNL)

Figure 4-1 shows EES market potential by application type in the USA, as estimated by Sandia National Laboratory. Market size and benefits corresponding to the break-even cost of EES per kW are estimated for each application separately. While this study only treats present market potential and only for one (large) market, it provides useful suggestions for considering the future EES market. The results indicate that no market exists for any application at present which is both high-value and large. For example, the application "Substation On-site", which means an emergency power source installed at a substation, presents a relatively high value, but its market is small. On the other hand, for the application "Time-of-use Energy", meaning time shifting at a customer site, a large market size is expected but its value is not high.

The study indicates that value and market size for each application can vary with circumstances in the future, and that one EES installation may be used for multiple applications simultaneously, which increases the benefits. One factor affecting the future market is the scale of new installation of renewable energies.

5.3EES market estimation by the Boston Consulting Group (BCG)

In this study, a price reduction in EES technologies is forecast for 2030 and the investment profitability by EES application is evaluated. Eight groups of

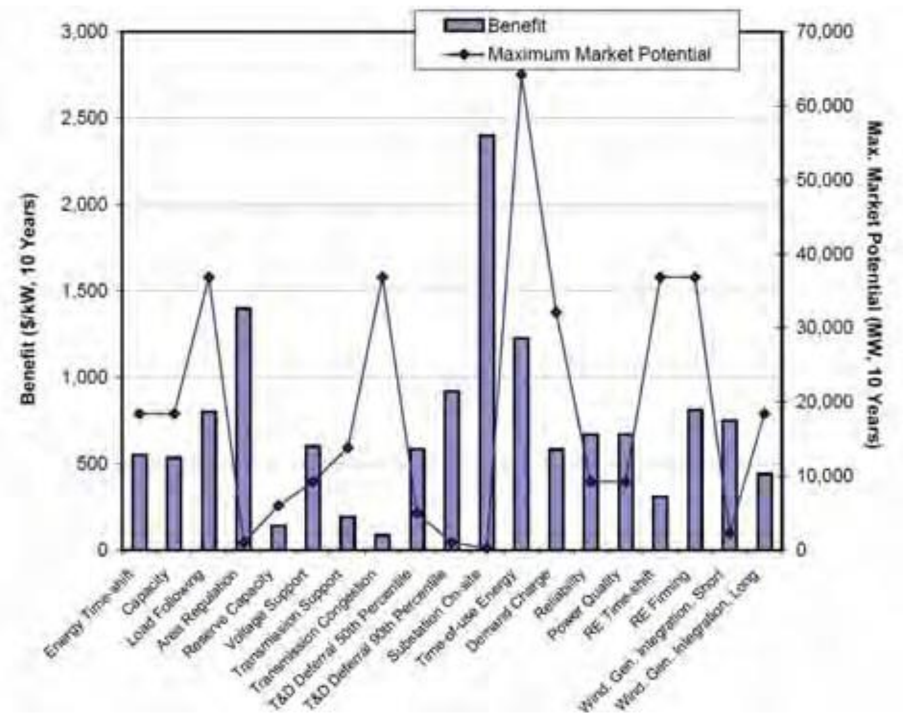


Figure 5-1 | EES benefit (break-even cost) and market size by application in the US [eye11]

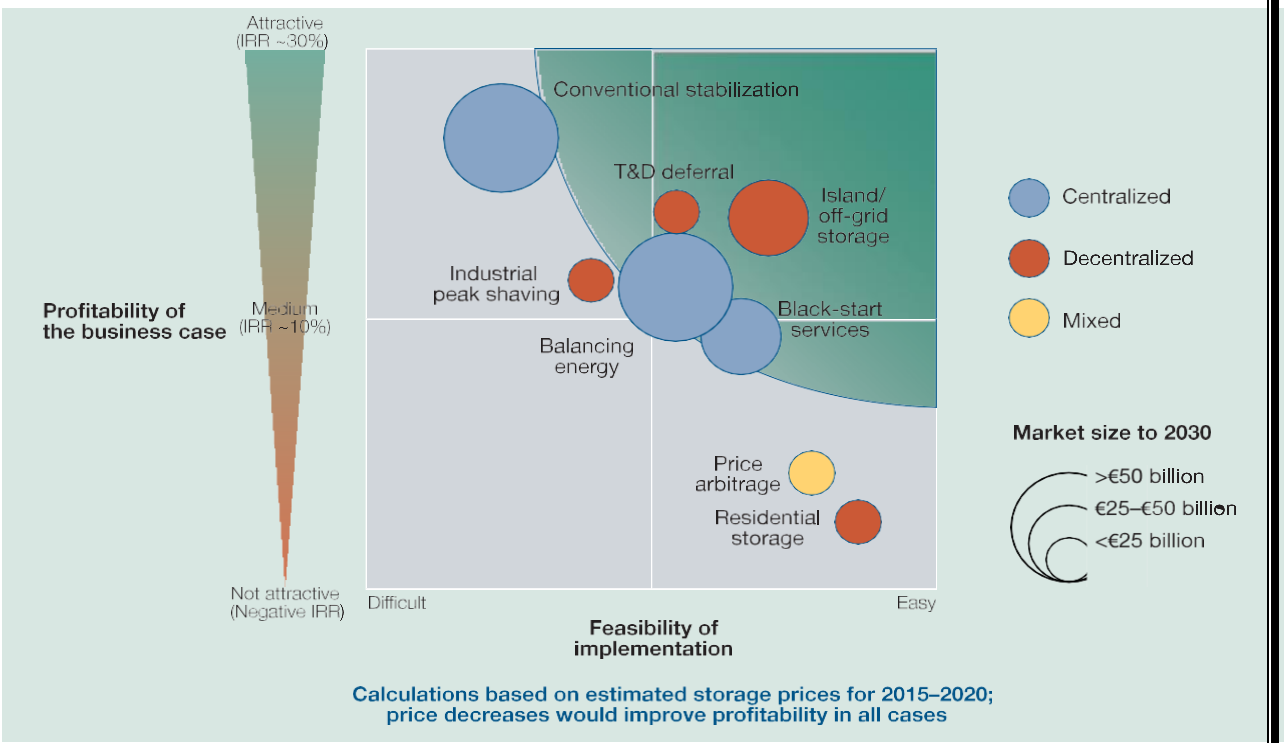


Figure 5-2 | EES market forecast by application for 2030 [bcg11]

applications are defined. To help determine the future EES market potential by application this study also evaluates the feasibility of implementation, which is made up of the existence of conventional technologies, technological difficulty of the EES technology development concerned, compatibility with the related existing business and the social circumstances. The results are shown in Figure 4-2.

The most promising market, where a large market and high profitability can be expected, is "Conventional Stabilization", where pumped hydro storage and CAES are applicable. Conventional stabilization includes time shift, smoothing of output fluctuations and efficiency improvement of conventional generators. The reason why this application is promising is that the need for time shift and smoothing output fluctuations will grow dramatically in accordance with the expected broad introduction of renewable energies.

Another attractive market is "Balancing Energy", which corresponds to adjusting power supply to meet demand that fluctuates within short periods. Large storage technologies such as PHS and CAES are already economically feasible in this application, and other EES technologies will have great opportunities in the future. The need for balancing energy is likely to rise as renewable energy generation causes fluctuations on the supply side to increase, and more and more power markets will introduce sophisticated market mechanisms for the procurement of balancing energy. The study concludes that total market potential for the eight groups of applications is 330 GW.

5.4EES market estimation for Li-ion batteries by the Panasonic Group

Panasonic Group (Sanyo) has estimated the EES market potential of the Li-ion battery. This

estimation was made by a simulation, with the following assumptions:

1. assuming that the trend of battery purchase prices will continue as determined by a market survey, and comparing with the future price of the Li-ion battery;
2. for utility use, assuming community energy storage and partial substitution of investment for transmission and distribution;
3. for UPS, assuming the probability of replacement of a lead acid battery by Li-ion to save space, for easy maintenance and considering the price gap;
4. assuming that growth in EV stations will be comparable to that in EVs themselves;
5. assuming no lithium shortage.

The result of the simulation, shown in Figure 4-3, indicates that the Li-ion battery market will grow steadily, and the residential market in particular will increase rapidly starting in 2017. There are, and will be, a wide variety of Li-ion battery applications, from small to large in battery size.

5.5 EES market potential estimation for broad introduction of renewable energies

The integration of renewable energies into the electric power grid can cause problems of output fluctuation and unpredictability. When the total volume of renewable energies connected to the grid exceeds a certain level such problems will appear and countermeasures will be needed. Ambitious plans with significant incentives for the introduction of renewable energies exist in certain markets (notably in the EU), and it is expected that EES will be a key factor in achieving the targets. For this reason some studies have been done to determine the amount of EES needed to match the planned introduction of renewable energy.

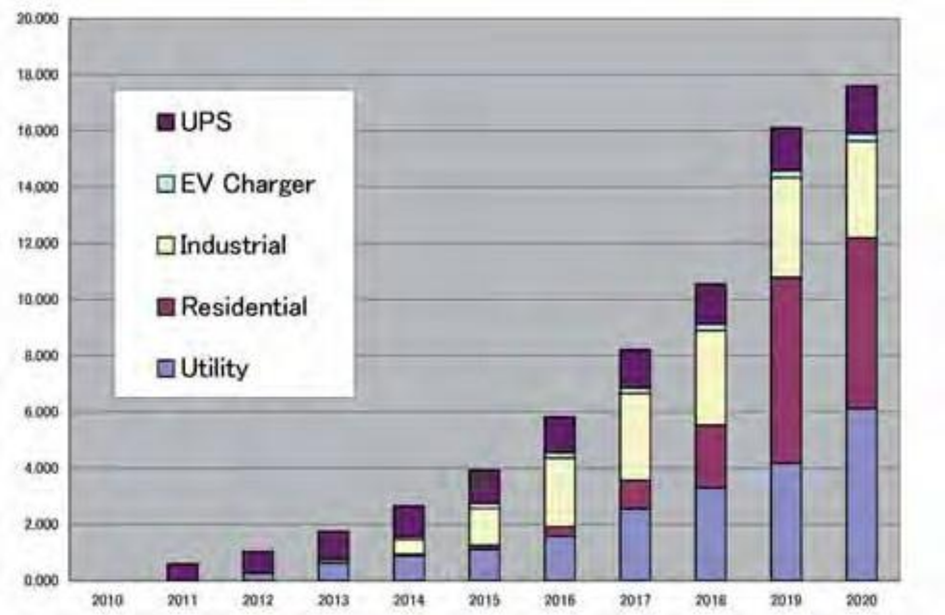


Figure 5-3 | Global market for Li-ion batteries *(Sanyo, 2011)*

5.6 EES market potential estimation for Germany by Fraunhofer

Germany is well known as a leading country for the introduction of renewable energies, so a large market for EES is expected. As shown in Figure 4-4, Germany has set a target to increase the share of renewable energy from less than 20 % to around 60 % to 80 % by 2030.

To achieve the German target more EES capacity is necessary: Figure 4-5 shows a scenario for wind production in the Vattenfall grid in 2030 which is estimated to be four times higher than today. The blue curve, representing wind power, shows a massive fluctuation resulting in huge amounts of energy which will need to be charged and discharged, while the red curve displays the actual load. The light blue field indicates the storage capacity in Germany in pumped hydro (40 GWh, 7 GW), which represents 95 % of total energy storage today [den10], and is totally inadequate for the quantity of energy which will need to be stored (area under the purple curve).

Figure 5-6 shows the estimation of required EES capacity by time range to handle the integration of

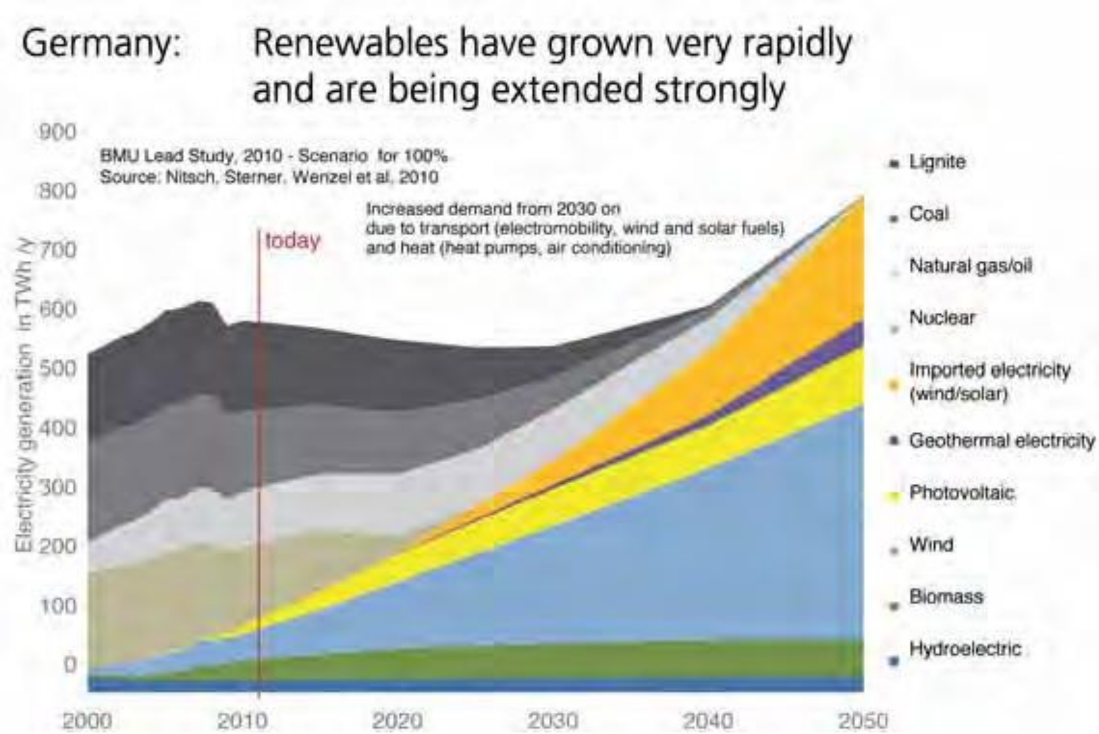
renewable energies in the past and future [ste11]. For both short-term and long-term needs a very large amount of EES will be needed to deliver peak power. In 2030 the following capacities are necessary (peak power multiplied by time):

- Hourly: 16 GWh
- Daily: 170 GWh
- Weekly:3.2 TWh
- Monthly: 5 TWh
- Total: ~8.4 TWh

The present installed storage capacity of 40 GWh PHS can cover only the hourly demand and a part of the daily demand. To cover the additional hourly and daily demand electrochemical EES such as batteries can be used. For the weekly and monthly demand, CAES, H_2 and SNG storage technologies are expected.

5.7 Storage of large amounts of energy in gas grids

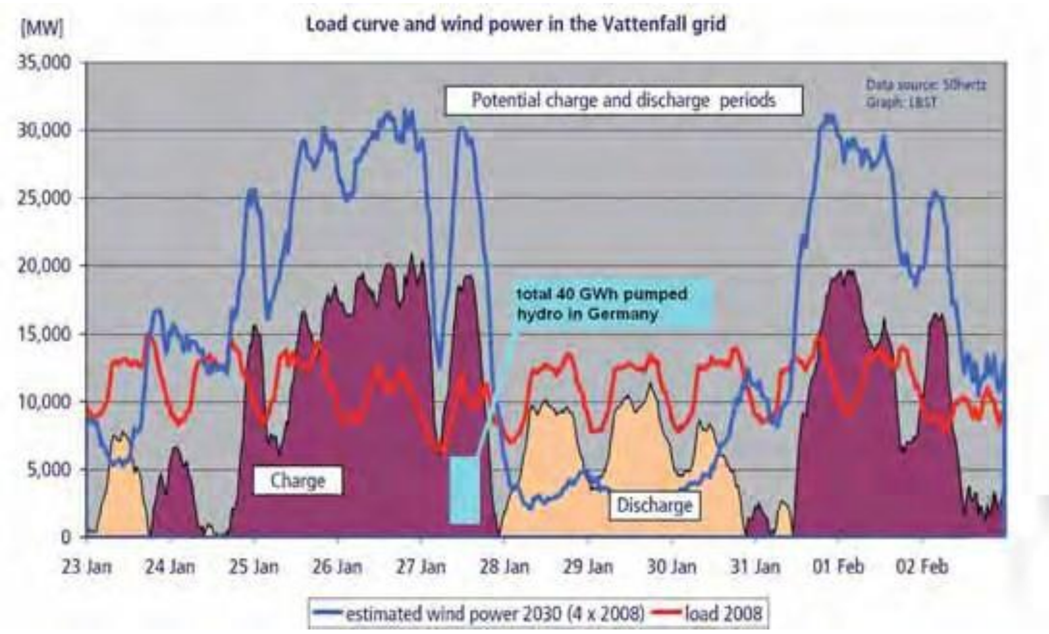
For the storage of large amounts of energy electrochemical EES would be too expensive



.

Figure 5-4 | Expected penetration of renewable energy in Germany [ste11]

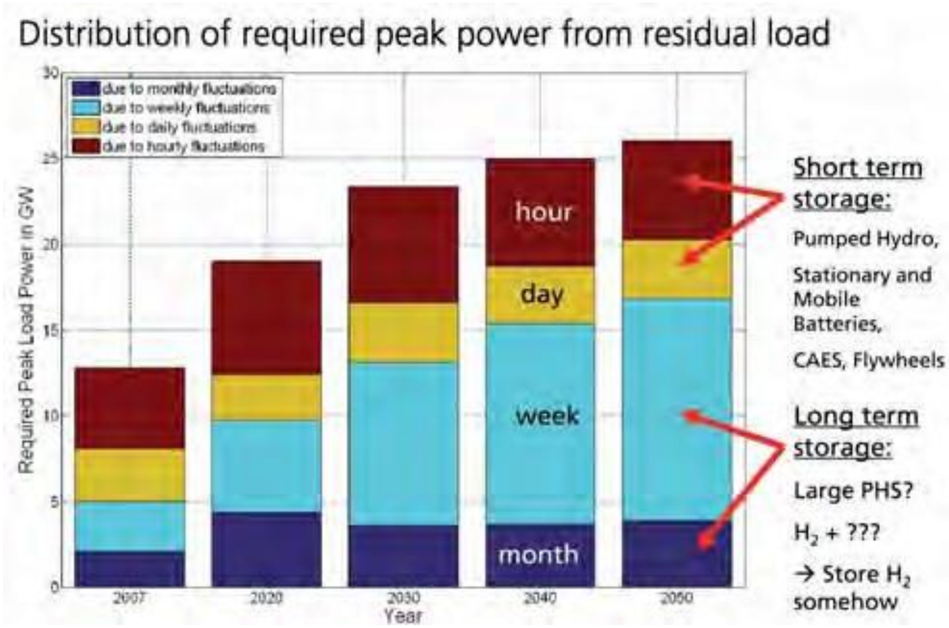
.



•

Figure 5-5 | Load curve (red) and wind power (blue) in the Vattenfall grid (north-east Germany): charge and discharge volume in 2030 in comparison with pumped hydro storage capacity [alb10]

•



•

Figure 5-6 | Distribution of required peak power for integration of renewables by time [ste11]

and require too much space. An alternative is the transformation of electricity into hydrogen or synthetic methane gas for storage and distribution within the existing natural gas grid (see sections 2.4.1 and 2.4.2). The efficiency of full-cycle conversion of electric power to hydrogen is about 55 % - 75 %, and to SNG about 50 % - 70 %. In Germany the storage capacity of the existing natural gas grid is very large, at about 200 TWh (about 400 TWh including the distribution grid). From a technical point of view it is possible to inject up to 10 % hydrogen into natural gas without any negative effects on the gas quality. Because hydrogen has one-third the energy of natural gas it is possible to inject hydrogen containing 7 TWh of energy into the natural gas grid. At any point of the gas grid it is possible to convert the gas back into electricity with a high-efficiency gas power plant (~60 %). In Germany in 2030 the weekly and monthly EES demand will be about

8.2 TWh (see section 4.2.1), which can nearly be covered by such an injection of hydrogen into the gas grid. This solution is only possible in countries where a gas grid exists; otherwise, the hydrogen or synthetic methane must be stored in additional high-pressure vessels (which normally presents no difficulties) or caverns.

5.8 EES market potential estimation for Europe by Siemens

Another study on the EES market potential to manage the issues caused by large amounts of renewable energies has been carried out by Siemens [wol11] [hof10]. This study covers the whole of Europe and adopts an extreme assumption, that *all* of the electricity is supplied by renewables (65 % wind, 35 % solar).

Since renewable energies are by nature uncontrol-lable, a mismatch between demand and supply can happen both in the geographic domain and the time domain. When there is a mismatch be-tween supply and demand, shortage of supply is conventionally backed up by a reliable power sup-ply such as fossil fuel generators. To avoid this, geographic mismatch in an area can be decreased by reinforcement of interconnections with neigh-bouring areas, and time mismatch can be solved by the EES time shift function. A simulation was carried out in order to determine how much EES would be needed if it alone, without any reinforce-ment of interconnections, were used to eliminate backup capacity (see Figure 4-7). Europe was di-vided into 83 areas, each with a different mix of renewable energy – in the figure, "EMix 1 % PV" for example means 1 % PV and 99 % wind. For the whole of Europe 65 % is generated by wind and 35 % by PV. The results show that 30 % - 50 % of the load needs to be backed up by fossil fuel generators if there is no EES ("0h" in Figure 4-7). The backup needed decreases to 10 % - 20 % of demand if EES equivalent to one week's load is available ("7d" in Figure 4-7), which corresponds to EES of 60 TWh or about 2 % of the annual demand (3 200 TWh).

In practice, for 100 % renewables, both reinforce-ment of interconnection lines and EES capacity of between 2 % and 8 % of the annual total demand is necessary. The value depends on how much re- inforcement of grid connections and over-dimen-sioning of renewables takes place. For hourly and daily storage the study suggests using PHS and electrochemical EES (NaS, Li-ion, LA or RFB). For the weekly and monthly demand CAES and H_2 are recommended. As an alternative for the weekly and monthly demand, large, new PHS in the TWh range in the Scandinavian countries (Sweden, Norway) is discussed. However, connecting these would need transmission lines over long distances. The financing and acquisition of such transmission lines seem to be difficult from today's viewpoint.

5.9EES market potential estimation by the IEA

Another study on the potential EES market to cope with massive renewable energy introduction in the world has been done by the IEA (International Energy Agency) [iea09]. In this study the necessary amount of EES is calculated in relation

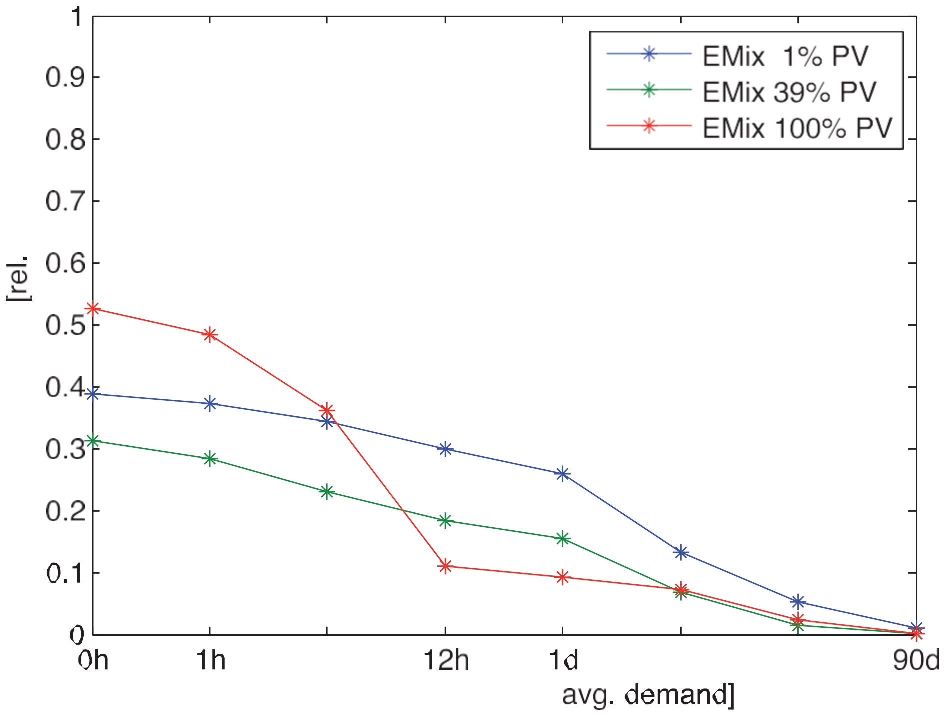


Figure 5-7 | Necessary backup energy related to EES capacity [wol11]

to variation of output from renewable energies. As shown in Figure 4-8, the required amount of EES increases with renewable energy penetration and the assumed output variation from renewable energies. For example, if the net variation in wind power is assumed to be 30 % of its rated output, the amount of EES needed in Western Europe will increase from 3 GW in 2010 to 90 GW in 2050 to keep pace with the forecast increase in wind power generation. The necessary amount of EES in 2050 can vary from 50 GW to 90 GW according to the assumed rate of net output variation in wind power between 15 % and 30 %.

In Figure 5-8, the necessary amount of EES by region is estimated based on the forecast of renewable energy introduction. Since high renewable energy penetration is expected in Western Europe and China, EES potential markets in both regions are relatively large. The necessary amount of EES in the world in 2050 is estimated at 189 GW or 305 GW, corresponding to an output variation rate of renewable energies of 15 % or 30 % respectively.

Total current EES capacity (mainly PHS) being 100 GW, a doubling or tripling of available EES will be needed (assuming perfect geographical distribution – otherwise even more).

5.10 Vehicle to grid concept

Depending on the probable development and spread of electric vehicles, there will be a great potential for power to be fed back from car batteries into the grid. The federal government of Germany has forecast up to one million EVs by 2020 [bmw10]. Including hybrid and pure EVs the average capacity is about 20 kWh per vehicle. In a scenario in which about 30 % of these capacities are used, we would have about 6 GWh available for energy storage. Compared to pumped hydro storage in Germany with capacities of about 40 GWh in 2011 this would represent about 15 % extra.

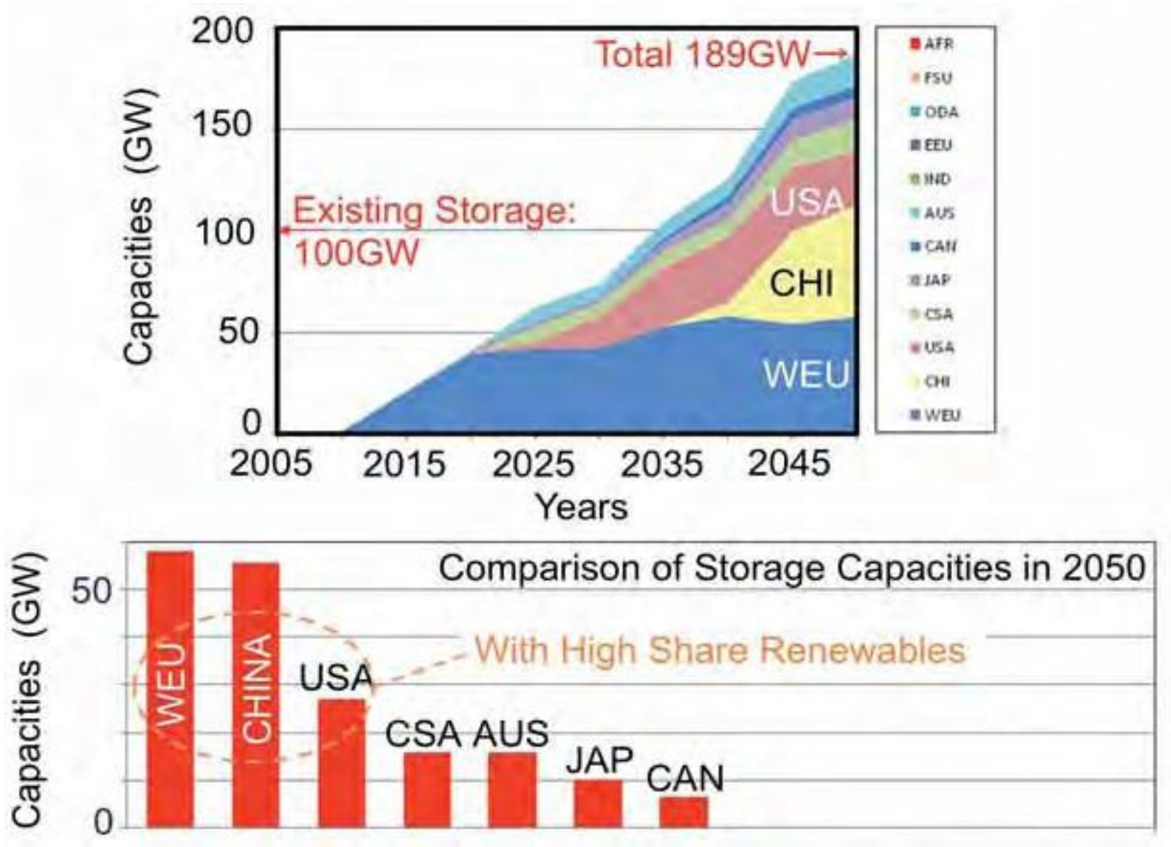


Figure 5-8 | Necessary storage capacity estimation by region (wind variation rate: 15 %) [shi11]

The IEA has also carried out a worldwide study on using EV batteries for mitigation of renewable energy output variations. If EV batteries are used for time shift and smoothing of short-term fluctu-ations by using vehicle-to-grid (V2G) technology, the EES needed can be decreased from 189 GW to 122 GW or from 305 GW to 280 GW in the two scenarios (see section 4.2.4). If these capacities are used in the future, grid operators will have more scope for short-term time shift and a higher level of security of supply can be guaranteed.

A field where development is needed is the reinforcement of the low-voltage power grid, whose infrastructure is not yet ready for the power feed-in of a large number of electric vehicles – the grid's limited transmission capacity would be overstretched. For the communication between vehicles and grid operators an intelligent system will also be needed, one acceptable to the consumer. Consumer acceptance will play a major role in the success of the V2G concept. Different business models are under discussion, e.g. one where the car owner is not the owner of the battery but rents or leases it, or pays for the electricity at a rate which covers the battery cost.

5.11EES market potential in the future

Several studies on market potential have been mentioned in this section; they have suggested the following conclusions.

1 The potential market for EES in the future is much larger than the existing market, mainly

driven by the extended use of renewable energy sources and the transformation of the energy sector, including new applications such as electric mobility. The market volume is related to the (future) renewable energy ratio and varies among regions.

2 If further cost reductions and technology improvement can be achieved, EES systems will be widely deployed,

for example, to shift the demand, smooth renewable energy output and improve the efficiency of existing power generation.

3 European studies indicate huge expectations for EES technologies to compensate for the fluctuation of renewable energy power output. Large installations of wind turbines and PVs may require numerous EES systems, capable of discharging electricity for periods from two hours up to one day. Hence the market for conventional large-scale EES, such as PHS and adiabatic CAES, is attractive. But in many countries such as Germany and Japan the future potential of PHS and CAES is very limited due to the lack of suitable locations or underground formations.

4 The extensive introduction of electrochemical EES such as NaS, Li-ion and RFB in the MW - MWh range is expected, for discharge times of hours to days.

5 Long-term energy storage is essential to achieving very high renewable energy ratios. The IEA report shows that further installation of renewable energy will lead to an insufficiency of thermal power generators for power control, and cause short-time output fluctuations. This scenario may be expected in Western Europe and China which have both set high renewable-energy-penetration targets.

6 To cover longer discharge times of days to months hydrogen and SNG technology have to be developed. The well-established natural gas grid and underground storage in regions such

as Europe can be (partly) used for H_2 and SNG storage.

7 Smart Grid technology using many small, dispersed batteries, such as EV batteries, is attractive for many applications. But even if all EV batteries are used for this purpose they will be insufficient to cover future demand for EES.

Given these studies, Table 4-1 shows which EES technology is or will become feasible for what applications, and where further research and development are necessary.

In addition to the conclusions above, Table 4-1 shows that Li-ion has great potential for many applications, but needs further careful development and introduction of mass production to achieve cost effectiveness. CAES, RFB and H_2 applicable to utility use for time shifting also need further development and mass production to achieve cost effectiveness. HFB and SNG, also potentially applicable to this application, need further fundamental research and development to achieve reliable and cost-effective produc