Decentralized energy systems will at least partially consist of on island systems with interconnections to the central grid but with a high degree of autonomy. In these constrained settings with a high share of fluctuating energy inputs from renewable sources, matching supply with demand will become more challenging than in a larger technical configuration, where a portfolio effect is more likely to balance renewable energy intake and backup capacities based on, say, gas-fired power plants are at disposal. If largely autonomous patches of grid infrastructure are established, adequate investments for facilities that store excess electricity have to take place.

The batteries of stationary storage devices and electric vehicles can serve as a buffer for fluctuating renewable energies, but technical obstacles, high unit prices, and consumer acceptance issues may delay their mass market diffusion. Under which business models is storage already today economically viable, according to market experts, or when will it become profitable beyond subsidies? How likely is it that batteries of electric vehicles will be integrated as bidirectional storage devices?

### Stationary storage

Storing electricity beyond laptop batteries and cell phones is more complicated than storing many other forms of energy. Several technologies that allow for large-scale storage have been developed up to a commercial stage, and some of them are in widespread use. One of the most effective and most often implemented technologies is pump storage, where hydroelectric plants are used not only for using the kinetic energy to generate power, but also to pump water from a lower to a higher reservoir in periods when excess electricity is available or particularly cheap. The process is reversible at a fairly high efficiency, so that differences in spot market prices can generate sizable
profits. However, pump storage depends on the geographical setting; its use is limited to mountainous or hilly regions. Since the hydroelectric potential in many industrialized countries is largely exploited and new projects often fail because of environmental protection legislation or resistance from local residents, the construction of new pump storage facilities will be limited.

Compressing air and squeezing it into salt caverns or abandoned mines is another technology for larger-scale storage solutions, but it will be possible only where the geological configuration of the ground allows for it. Despite a fairly large potential, it is only in use in a few locations in the world (Swierczynski et al., 2010). Fly wheels and high-temperature storage have not successfully spread into the market because of high costs and technical obstacles, but they may be used in some niche applications. Ultracapacitors and capacitors store energy in electrically charged plates, and not through an electrochemical reaction as with batteries, which allows for a high number of rapid charge and discharge cycles and a higher power density. In stationary applications, they may be used to provide short-term balancing reserves, but have not yet reached full commercial viability (Pike Research, 2011).

Hydrogen, by contrast, may become a widespread, decentralized solution in the future. Wind turbines or photovoltaic cells can provide the electricity to split water into its components, oxygen and hydrogen, via a chemical process called electrolysis. The hydrogen can then be stored and recombined with oxygen with fuel-cell technology. Most recently, the natural gas grid is being discussed as a candidate for storing hydrogen and using it for combustion, so-called power-to-gas technology. First pilot plants like German utility E.ON’s Falkenhagen facility are projected to start producing hydrogen by 2013 (see also Dena, 2012).

Storing large amounts of electricity in stationary batteries has been implemented only under specific circumstances, for example in West Berlin during the Cold War, when power supply was a geopolitically sensitive issue that could have been easily used as a strategic instrument by East Germany and its allies. Major reasons for the limited use of batteries are high costs for battery stacks and low energy density under current technologies.

However, with the emergence of decentralized, largely autonomous subsystems, stationary storage devices will gain importance in the coordination of supply and demand.

As more and more renewables enter the grid, it will be more challenging to even out fluctuating supply. Because an increasing number of houses employ heat pumps and more functions are replaced by electricity, demand will both grow and become more erratic. As a consequence, it will be more challenging, and thus more costly, to balance supply and demand. All this will create demand, and hence additional business models for