ELECTRICAL ENGINEERING SERIES

Electrical Energy Storage for Buildings in Smart Grids

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Foreword

In this third volume, the final work in a definitive survey of electrical energy storage, Professor Robyns and his colleagues discuss the environmentally responsible energy solutions which are currently available for use in the building sector, for residential or tertiary usages. As in the previous volumes, the authors have applied a rigorous methodology for designing supervisors using fuzzy logic, a means of managing energy flows in an optimal manner, taking account of a large and varied range of constraints.

The task that the authors set for themselves was not an easy one, as their ambitions for the work grew over time, building on their accumulated experiences. Their aim in this book is to offer innovative solutions for systems which are extremely complex, a result of the dense network of interconnection and of the number of actors involved. One example is that of eco-neighborhoods, which, in addition to the capacity to be self-sufficient in energy, are designed to enable newcomers to slot in easily using a “plug-and-play” model. For instance, the smooth integration of charging facilities for the increasing number of electric and hybrid vehicles on our roads – a number set to increase substantially over the coming years – is essential. For this reason, as the authors rightly note in the introduction, it is also crucial that we take account of the public acceptability of new energy solutions: these will affect the whole population, not just in the public sphere but also in the home. The current debate concerning the large-scale rollout of smart meters to measure energy consumption is a striking illustration of this.

Once the authors have risen to the challenge that they set themselves, producing yet another exceptional book, featuring a clear and accessible presentation of the issues alongside a selection of relevant examples, rigorously examined using a comprehensive methodology. Anyone concerned with the ongoing shift in the energy paradigm, a crucial concern for our society, is sure to draw inspiration from this work to support their own work and reflection.

Eric MONMASSON
University of Cergy Pontoise
SATIE Laboratory
Paris, September 29, 2018

Introduction

In France, in 2016, residential and tertiary sector buildings represented 45% of total final energy use. The proportion of electrical energy continues to increase, currently representing approximately 37% [MIN 17]. There is thus much to be gained by increasing energy efficiency in this area, equipping buildings to produce and store energy and establishing intelligent energy management systems, interacting with the distribution grid.

Current developments in the sphere of renewable energy and the trend toward self-production and self-consumption of electrical energy produced onsite have led to increased interest in the means of storing electrical energy, a key element of sustainable development. Self-consumption provides a stimulus for better mastery of energy consumption and leads to a reduction in electric bills (reducing costs associated with connection to the main distribution grid, subscribed power and, potentially, taxes). Collective self-consumption can result in additional optimizations, grouping together buildings with different consumption profiles in terms of time. Considerable gains may also be made through load management, modulating consumption by adjusting loads or through local production and self-consumption, with or without a storage system. Finally, in addition to these financial aspects, collectives may benefit from using renewable forms of self-consumption (one of the main aims in such cases), as there are several potential sources of production (notably solar panels on roofs). The consumption of locally produced energy also prevents or limits losses associated with the transportation of energy over long distances.

The increase in popularity of electricity as an energy carrier for buildings can be attributed to the flexibility which it offers, as well as to the potential to avoid pollution at the usage site. In the coming years, an increasing proportion of these buildings will be equipped with storage systems, providing emergency backup, compensating for natural variations in renewable energy supplies, and will also be able to provide services for the wider electric system. Storage systems are expensive, and shared usage offers a means of spreading the cost, while contributing to the management of system aging. At the time of writing, studies are being carried out with regard to using the storage capacity of electric vehicles to provide services to the electric distribution grid or to the buildings where they recharge: these solutions are known as Vehicle to Grid (V2G) and Vehicle to Home (V2H). Similar solutions would be possible for integrated storage in commercial and tertiary (with offices) buildings, or, indeed, whole residential neighborhoods.

The aim of this book is to increase awareness of the potential offered by these developing technologies, in the context of buildings, groups of buildings and/or neighborhoods, integrated into large “smart grids” or forming smaller “micro grids”, particularly with regard to their management and valorization.

Storage will form an essential element of future smart grids, but these networks will be unable to attain their full “smart” potential without collecting large amounts of data, via connected meters, among other things. The installation of these meters raises ethical questions with regard to the protection of the data which they generate, which should give a precise indication of the energy usage habits of consumers, but is also affected by questions of cybersecurity.

The development of self-consumption of locally produced energy raises other ethical questions of a fundamental nature: energy, particularly electricity, has become essential to maintaining the lifestyles of industrialized societies, for comfort, sanitation, security, education and more. Self-consumption challenges the current electrical supply model, which is highly centralized in terms of both production and management. We are effectively facing an energy revolution. In extreme cases of self-consumption, in which public network management entities are left out of the picture altogether, this could be compared to the “uberization” (an exchange of services between private individuals to the exclusion of larger companies, enabled through the use of Internet applications) recently seen in the contexts of urban automobile transport and short-term lets. However, access to electricity is essential to the operation of our societies, which are highly dependent on this energy supply. Self-consumption could also undermine the French principles of energy solidarity and equal access to energy (in terms of cost). These last points raise further ethical questions, particularly with regard to an increased risk of energy poverty and even energy-based communitarianism. There is a danger that self-consumption may simply benefit those consumers who are already in a strong position – for example wealthier households with the financial capacity to install solar panels on the roofs of their houses.

Furthermore, self-consumption is largely based on the use of "new" renewable energy sources (essentially solar, as well as wind power), which are, by their very nature, variable and weather-dependent, fluctuating significantly with the seasons and from day to night. This being so, climate change is a source of additional uncertainty with regard to the future behavior of these new technological solutions.

For these reasons, we would do well to adopt an ethical rule set out in [GIO 18]: "Do not leave your children to solve problems which you yourself voluntarily created, which are of vital importance for your descendants, and for which you are not sure that a realistic solution exists or will be found in the future. Furthermore, any advances resulting from the scientific discoveries and/or technological developments in question should support the common good and promote the restoration of original ecosystems, if these systems created balance and harmony, wherever possible".

This does not mean that we should limit research into the development of smart grids and self-consumption; instead, these projects should be subject to regular ethical review in connection with the questions set out above (even though the risks seem smaller and of a different nature to those associated with the development of nuclear power). An interdisciplinary approach to these questions is necessary, connecting science and sociology, economics, ethics and even, where applicable, legal considerations. Law-makers have a key part to play in providing an "ethical buttress" [GIO 18] for new methods of energy production and consumption.

In Europe, Germany leads the way in terms of electrical self-consumption, with 500,000 installations in 2018, compared to 20,000 in France, where a regulatory framework has yet to be fully defined. Debate centers on the notion of locality as it relates to self-consumption, a notion that may be defined in various ways. It may be limited to part of the distribution grid (e.g. downstream of a medium-voltage to low-voltage transformer substation [CRE 18] serving part of a residential neighborhood) or to a distance, for example a one-kilometer radius around a production facility [MIN 18] enabling energy exchanges between large-scale service buildings in addition to homes. There are also questions regarding taxation: for example, in France, a tax is levied to support the development of renewable energy, and self-supply installations of under 9 kW [CRE 18] or 1 MW [MIN 18] may be exonerated. Finally, the charges for use of the public distribution grid by collective self-consumption, which only use a small portion of this network, need to be determined; these entities must remain connected to the grid to ensure that supply is maintained even though their renewable systems are not producing electricity and there is no power stored on-site.

The aims of this book are:

– to highlight the importance of storing electrical energy in the context of sustainable development, smart buildings, smart grids and smart cities;

– to demonstrate the variety of services which electrical energy storage may provide;

– to consider the socio-economic questions associated with changes stemming from the emergence of smart buildings and smart grids, providing elements of response;

– to present methodological tools for the design of a management system for stored energy, following a generic and pedagogical approach. These tools are based on causal approach, artificial intelligence and explicit optimization techniques. They will be presented throughout the book, in the context of real-world case studies;

– to illustrate these methodological approaches through the use of various real-world examples, used as a basis for clearly explaining the integration of renewable energy and electric vehicles into our environment (buildings, energy sharing between residential and tertiary buildings, urban neighborhoods and rail energy hubs).

In Chapter 1, we will describe the issues surrounding electrical energy storage in buildings, blocks and neighborhoods, whether integrated into a large smart grid or forming their own micro grid. We will highlight the storage requirements for these applications, alongside the services which they may provide. The socio-economic aspects of these developments will be touched on briefly; a more detailed discussion of these elements is provided in Chapter 5. We will also introduce a methodology for designing a management system for energy storage systems. This system is particularly suitable for the management of complex systems, featuring elements of uncertainty regarding the production of variable renewable energy, consumption (which is also variable) and interactions with the wider grid. Our methodology, based on fuzzy logic, is designed to respond to a number of requirements involving real-time treatment.

Chapters 2–4 concern cases involving a single entity: a commercial building, a tertiary building connected to a powerful network and an energy producer in a zone which is not connected to a larger network. These entities may be consumers, producers and storers of electrical energy.

Chapter 2 concerns the development of an energy management system for a commercial building such as a supermarket, integrating photovoltaic solar energy production and energy storage. Fuzzy logic is used to design an energy management strategy for the storage system. The storage system regulates the power drawn from the electrical network during peak and off-peak periods in such a way as to reduce electric bills and CO_2 emissions, while promoting self-consumption through the use of solar panels. Energy may be stored in a dedicated system, as well as through the use of adjustable loads. We present the results of simulations and compare various topologies (with or without photovoltaic generation and a storage system) on the basis of economic and ecological indicators.

In Chapter 3, we discuss the combination of three different technologies – variable intensity LED lighting responding to external luminosity, photovoltaic energy production and batteries – operating in a tertiary sector building over a dedicated DC (direct current) network. This configuration creates an intermittent production/intermittent charge/storage system which is designed to reduce certain electronic conversion stages. By maintaining a connection to the AC (alternating current) distribution grid, the system must guarantee energy supply for lighting purposes and eventually may supply power to the AC grid. To ensure that the system is able to respond to user needs in terms of lighting and to support the operation of the AC grid, while favoring consumption of solar electricity produced on-site, a real-time energy management system is developed using a methodology based on fuzzy logic, applied to the case of a DC network architecture.

In Chapter 4, we present a photovoltaic system with hybrid storage combining two different technologies: electro-chemical batteries and super-capacitors. This hybrid approach aims to combine the advantages of each technology in order to increase the life expectancy of the storage system and to maximize overall yield. The system in question is designed to supply electricity to island or isolated habitats. A supervisory algorithm based on fuzzy logic is also presented. The main objective in this case is to monitor a projected production program while respecting the constraints operating on the electric network management system (power smoothing, frequency control, etc.). A comparative study of different storage configurations, particularly with regard to the life expectancy of storage elements and average energy cost, is also presented.

The full innovative potential of smart grids can only be released by promoting interaction between the different actors involved in the electric system (producers, consumers, storage and network operators), increasing their "electrical intelligence". These actors may have very different consumption and production profiles, with very varied economic and social objectives and/or constraints. New types of actor may emerge alongside new economic models, all of which may contribute to solving energy and climate issues, promoting the development of renewable energy sources. It is important that all actors should benefit in these cases, including those in situations of "energy poverty". These questions and issues will be discussed in Chapters 5–8, which present several case studies involving very different actors.

In Chapter 5, we highlight the diversity of actors involved in a smart grid, defining the rationale of individuals, which may vary and may impact a whole group of actors. We also address the issue of economic and sociological changes brought about by the use of smart grids, including changes to the value chain, contractual models, socio-economic profiles of consumers and governance. The social acceptability of mass participation in energy management is also discussed, particularly with regard to load management in multi-actor commercial buildings (e.g. shopping malls) and in a domestic context (households in residential buildings).

Chapter 6 concerns possible exchanges of electrical energy flow and services between a commercial building, such as a supermarket, and other actors such as renewable energy producers, network operators, third-party consumers (e.g. residential buildings), an electrochemical battery storage system and a diesel generator, all grouped together in a network for the purposes of self-consumption. We need to define ways of managing these exchanges, financial sustainability and acceptability for all of the actors involved, from energy professionals to consumers. Our study concerns a collective self-consumption system established between actors in a given geographical zone. First, we will present a case study concerning energy mutualization between commercial, tertiary and residential buildings, introducing the notion of an energy service aggregator. We will then present a method of energy management based on fuzzy logic, as applied to our case study. A specification will be established for each actor, drawing on expertise provided by a sociologist in order to assess the conditions of acceptability and the implication of each actor in the energy mutualization process. We then propose the introduction of a load management acceptability coefficient, to be integrated into the supervision strategy. Several different scenarios, with and without energy management, will be compared on the basis of economic, environmental, self-production and self-consumption indicators.

Chapter 7 concerns the management of a local energy community such as an eco-neighborhood. The objectives considered include increasing energy efficiency in the neighborhood and reducing CO_2 emissions by increasing the production and use of photovoltaic energy in the local energy network, which also includes energy storage systems and gas turbines, which must be used in an optimal manner, while guaranteeing the operation and stability of the neighborhood network. This can only be attained by achieving a balance between supply and demand. The aim here is to identify the best way of exploiting production capacity in response to an increase in new uses of electricity (such as electric vehicles), and also to develop evolutive energy management systems into which new production mechanisms can be integrated with ease. Our method aims to predetermine the production profile of generators so as to ensure global optimization of an objective function for the urban electrical network, then to adjust operating points over the course of a day to account for any differences identified through a communication network. There may be several possible solutions, so our two-level optimization approach is designed to identify the best option for any system in order to:

– maximize production from renewable sources by taking account of availability, which depends on weather conditions, and of their usage within the electric system in order to promote self-consumption;

– minimize the cost of energy production within the micro-grid;

– minimize the equivalent CO_2 quantities emitted by conventional generators.

The batteries of electric and rechargeable hybrid vehicles will, in future, represent a significant amount of storage capacity, and this may be exploited by the electric grid when vehicles are plugged in. It may also be used, more specifically, by buildings. A variety of different technologies will be presented in Chapter 8:

– Vehicle to Grid (V2G): the vehicle (via its battery) feeds into the electric grid through a charging point on a public thoroughfare or carpark (station, shopping mall, etc.);

– Vehicle to Home (V2H): the vehicle powers a home, generally one cut off from the electric network;

– Vehicle to Home and Grid (V2HG): the vehicle powers a home which is also connected to an external electric network, meaning that the vehicle can feed into or draw power from this network;

– Vehicle to Building (V2B): the vehicle powers an apartment or service building. Evidently, in this case, there would be several vehicles in a carpark;

– Vehicle to Station (V2S): the vehicle powers a railway station building or railway equipment, and vice versa. Again, this situation would involve multiple vehicles.

Finally, Chapter 8 introduces different configurations which may be used to exploit the reversibility of the charge in electric vehicles such as those described above. The potential services and energy management questions associated with a fleet of electric vehicles interacting with an electrical distribution network will be discussed in greater detail. We will also describe an energy supervision system based on fuzzy logic, and look more closely at the uses of reversible charge in the context of train stations.

1

Storing Electrical Energy in Habitat: Toward "Smart Buildings" and "Smart Cities"

1.1. Toward smarter electrical grids

1.1.1. *The move to decentralize electrical grids*

The traditional organization of an electrical grid is based on centralized management, at the level of the transport grid to which conventional nuclear, thermal or hydraulic production systems are connected. Originally, the distribution grid only supplied consumers, and only carried power flows from high voltage points, through connections to the transport grid, toward lower voltage points. The possibilities for adjustment at the distribution level are limited, and ancillary services (voltage and frequency control) are provided by production units connected to the transport grid [ROB 12c, ROB 15].

The development of decentralized production, generally low power, unplanned and not monitored by a central entity, has brought about significant changes. Producers are often connected to a distribution grid and dispersed across a territory, contrasting with the classic model of high-power production on a few, clearly defined sites. The effects of integrating this production, which generally comes from wind and solar sources, are becoming increasingly noticeable and bring in new constraints. The variable nature of wind and photovoltaic sources, which is difficult to predict, adds a further level of complexity to grid management issues.

The liberalization of the electricity market within the European Union, beginning in the early 21st Century, has resulted in a clear separation between the management of energy production, which is subject to competition, and the management of

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transport and distribution grids: evidently, the infrastructure involved cannot be duplicated. In France, the CRE (*commission de régulation de l'électricité*, Electricity Regulation Commission) [CRE] is charged with ensuring that the new competition mechanisms are respected, that competition does not have a negative effect for consumers and that there is no danger to an infrastructure crucial to both the economy and security of the country. Liberalization has led to a need for new approaches to managing the electricity system, alongside new market mechanisms integrating the characteristics of new decentralized sources. Given that the electricity grids themselves cannot be rebuilt, development is needed at three specific levels:

– at the source level, using the possibilities offered by power electronics to develop new control and supervision strategies and provide ancillary services, notably through the implementation of energy storage; to develop multi-source systems (integrating intermittent renewable production, classic, predictable sources and storage) featuring integrated and optimized energy management [ROB 15];

– at the grid level, rolling out smart grids and developing new grid architectures, such as micro-grids, in order to increase the efficiency, security and availability of electricity grids, and increasing energy storage capacity, either at a central point or dispersed across these grids [ROB 15];

– at the consumer level, in industrial processes, tertiary buildings and homes, through electric and rechargeable hybrid vehicles, and in guided transport systems (trains, subway systems and trams) [ROB 16], with the aim of modulating energy demands to correspond to consumption, renewable production availability and the constraints inherent in electric grids.

Interactions between these different aspects need to be coordinated to some extent, and this raises questions regarding the optimal and most acceptable level of decentralization; a system for communication between components is also required. These issues are not purely technological in nature, including economic and sociological aspects, and requiring new developments on the judicial stage.

1.1.2. *Smart grids*

It is thus essential that we install and use new communication technologies as part of advanced management mechanisms. The level of intelligence in a grid depends on two factors. The first corresponds to the installation of a telecommunications network, mechanisms and equipment for remote control and automated network management within transport and distribution grids. The second involves advanced management of production (centralized and/or decentralized) and of loads, notably via the development of new products and services by producers and distributors, including network managers which increase the level of freedom available in piloting a grid. Final consumers may also benefit from special services and pricing offers, allowing the adoption of ambitious approaches to mastering instant demands for electricity and the integration of renewable energy sources (Figure 1.1).

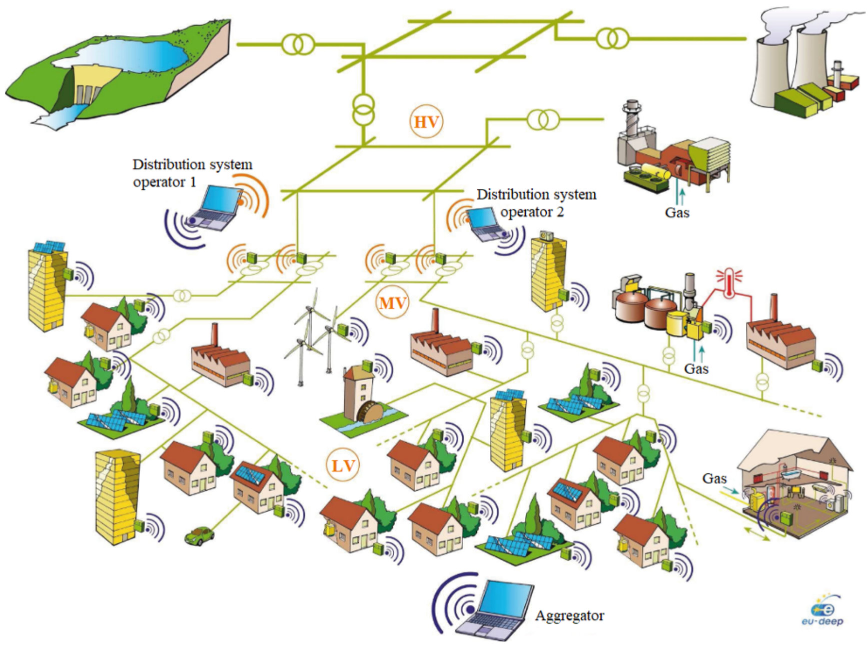

Figure 1.1. *Example of a future smart grid, including the distribution of regulation capacities across multiple sites via the Internet. HV = high voltage grid, MV = medium voltage grid, LV = low voltage grid (EU-Deep project). For a color version of the figures in this chapter see www.iste.co.uk/robyns/buildings.zip*

There are important issues to consider in relation to the infrastructure and reliability of communication grids, the "top layer" of infrastructure management software, the normalization of communication processes, and the security and confidentiality of data. Rapid and efficient management of extremely large quantities of data is essential for an electric system of this type to function effectively. For example, grid topology may need to be altered in response to an accident, or customer erasure may be decided upon in accordance with their contract conditions, in response to an unexpected change in local consumption. The rollout of large numbers of captors and measurement instruments (such as the Linky connected meters in France) means that the volume of information produced and used to manage the electric system is constantly increasing. A modular, evolutive and extendable grid architecture is therefore necessary.

In France, in 2016, buildings absorbed 45% of total final energy consumption (across all energy types). It is thus crucial to increase their energy efficiency and to develop their capacity to produce and store energy, integrating mechanisms for efficient energy management in connection with the existing distribution grid.

1.2. Storage requirements in buildings

A priori, buildings which are directly powered by the grid have no need to store electrical energy, with the exception of certain critical buildings which have their own backup supply for safety and security reasons, maintaining services such as lighting in public buildings, ensuring equipment continues to function in hospitals or guaranteeing that certain business systems continue to operate to avoid economic losses (e.g. data servers or sites devoted to specific sensitive industries). Renewable energy, which may be produced locally using solar panels, for example, creates different requirements. The inherent variability of production, uncertainty in predictions and the priority given to local consumption, reducing transportation losses, create a greater need for local electrical storage. Unlike onboard systems, storage solutions in buildings are not subject to weight constraints as they are not carried by the system; however, volume remains a significant consideration. Another point to consider is that the grid used should correspond to the application, for example in terms of DC voltage and current.

The increase in the use of electrical energy in buildings is due to the flexibility it offers, as well as to the fact that pollution may be avoided at the point of use. If electricity is produced by burning fossil fuels at a power station, for example, the pollution emitted – including greenhouse gases – will not be released in the building itself, but elsewhere, i.e. at the power station. In order to reduce emissions, electricity needs to be produced using non-polluting renewable resources; furthermore, construction and de-construction phases of the production unit need to minimize consumption of energy from non-renewable sources, and, more generally, polluting emissions need to be minimized across the whole lifecycle.

Storage systems, which will become increasingly present in buildings in coming years, respond to the needs of these applications, compensating for the variation in renewable energy production while potentially providing services for other actors in the electrical system. Although prices are likely to decrease somewhat, storage systems remain expensive; the provision of services to other actors is a means of financial valorization, as long as the implications of aging are also taken into account. In this regard, work is currently ongoing to identify ways in which electric vehicles may provide services to the electrical distribution grid, or, more locally, to the buildings to which they are connected for charging purposes; this is known as Vehicle to Grid (V2G) [SAR 13, SAR 16a] or Vehicle to Home (V2H) [VEN 16, VEN 17]. The same considerations apply to storage systems included in commercial, tertiary (office) buildings and residential neighborhoods.

1.3. Difficulties in storing electrical energy

The main drawback of electric power is the high cost of storage. While electrostatic energy and magnetic energy can be stored (in capacitors and superconducting magnetic energy storage, SMES, respectively), these solutions only provide a very partial response with regard to the timescale under consideration. To obtain high-capacity storage at an acceptable price, electrical energy must be transformed into another form of energy. Electrochemical storage, using lead batteries, has long been used for onboard applications and emergency power supplies. Storage in the form of kinetic energy, using flywheels, has been used over the last few decades in fixed applications such as emergency power supplies and for certain onboard applications, for example in satellites.

Electrochemical batteries store electrical energy supplied in continuous form. Flywheel storage involves electrical machines which must be able to operate at variable speeds, i.e. variable frequency. Since the grid provides electricity in the form of alternating voltage and current at a fixed frequency, these storage techniques were little used until the development of power electronics in the 1970s. We now possess the capacity to transform the form and characteristics of currents and voltages as required.

Ragone plots, showing power density and energy density, are often used to compare different technologies and highlight the specific energy/power balance of each [ROB 15]. Figure 1.2 shows a simplified example, comparing several electrochemical technologies and supercondensers [MUL 13].

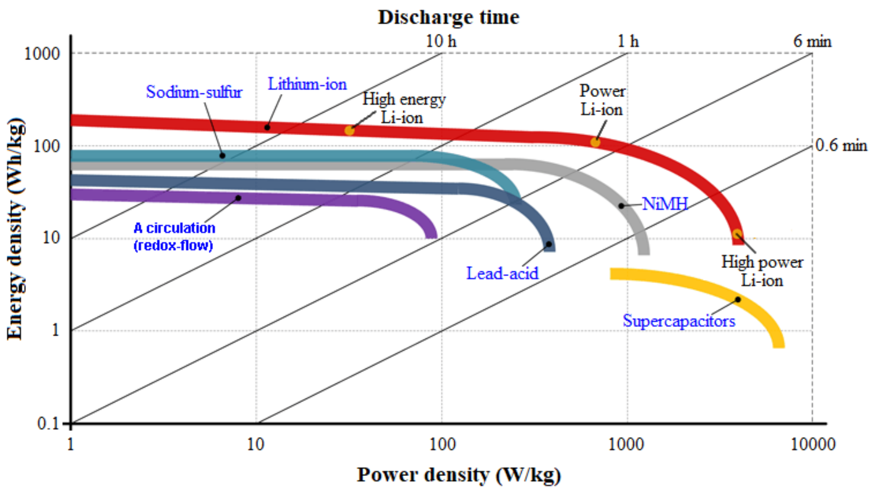

Figure 1.2. *Example of a Ragone diagram showing several electrochemical technologies and supercapacitors [MUL 13]*

In addition to power and energy, we need to take account of factors including life expectancy, response time and yield.

Life expectancy still represents a major technological constraint with regard to battery usage. It depends on the temperature of the battery, which should be neither too high nor too low, the frequency of charge–discharge cycles and the depth of discharge (DoD). The manufacturers of electrochemical solutions give figures of between 1000 and 10,000 charge–discharge cycles, with a maximum DoD and for a specified range of operating temperatures. Based on daily charge–discharge cycles, life expectancy thus varies from 3 to around 20 years. Life expectancy may be increased by reducing the operating temperature (e.g. via air conditioning) and DoD.

The energy capacity of supercapacitors is considerably lower than that of batteries, but they provide far higher power dynamics and a longer life expectancy in terms of charge–discharge cycles, in excess of 10,000. The combination of supercapacitors with Li-ion batteries is a useful solution for dynamic global storage systems, providing high storage capacities with high life expectancy. The supercapacitors handle rapid electrical variations, while the electrochemical batteries respond to regular energy needs. Note that flywheel storage systems can also provide high dynamic levels with a far higher number of charge–discharge cycles than that which is possible with electrochemical batteries [ROB 15].

Hydrogen is another possibility, enabling electricity to be produced via a fuel cell, and it can be produced from electricity (from renewable sources, for example) using an electrolyzer. However, the yield of the charge–discharge cycle is relatively low at approximately 25–30%; this means that the cost over a lifecycle remains excessive for the moment.

In the context of buildings, direct energy consumption presents the advantage of a better overall energy yield. The energy conversion required for storage results in losses, which differ widely depending on the storage technology in question. Over a full cycle, these losses may vary from less than 10% to 50%, or even more in the case of hydrogen. Nevertheless, this notion of yield needs to be relativized if stored energy comes from a source where energy shedding is used in the case of overproduction, for example in wind or solar power. We need to look at the overall balance in order to identify the best strategy (shedding or storage with a certain rate of loss) in response to economic or even environmental criteria.

Finally, note that electrical energy may be stored as a different form of energy before being used. This is the case for hot water tanks in domestic networks, where energy is finally used in thermal form, and for hydrogen produced through electrolysis, which may then be used for combustion. Certain loads include storage capacities which may be exploited to give flexibility by modulating their power supply from the grid. This is the case for cold storage in supermarket freezers, for example, and for storage in the batteries of electric vehicles.

1.4. Electricity supply in buildings

1.4.1. *Building supply and consumption*

The electrical energy consumed by buildings may be produced locally or supplied by the distribution grid. Buildings are generally powered by the grid, unless they are isolated (e.g. a mountain chalet) or have their own power supply. This situation is increasingly common with the development of renewable wind and photovoltaic solar supplies.

Figures 1.3 and 1.4 show typical profiles for domestic and commercial consumers. They show the way in which consumption varies depending on the time of day, the season and the load type.

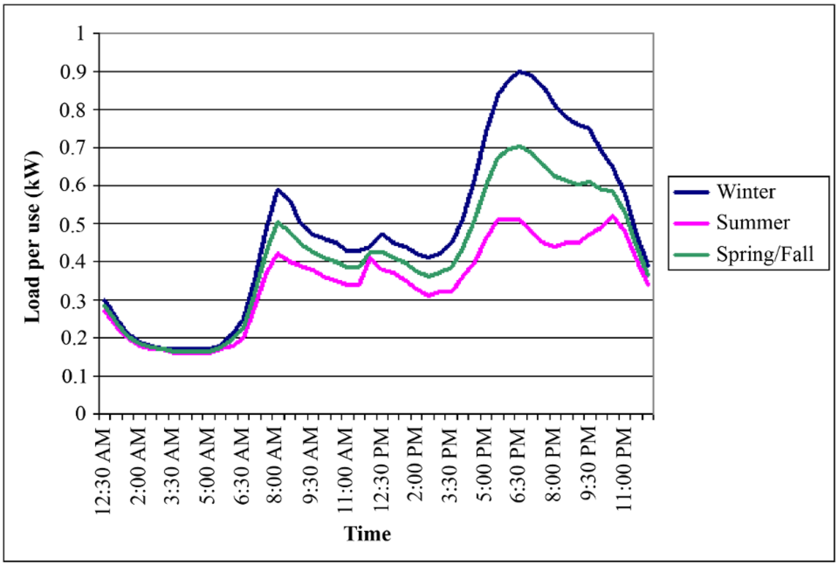

Figure 1.3. *Typical profiles for domestic consumers excluding electric heating (RTE)*

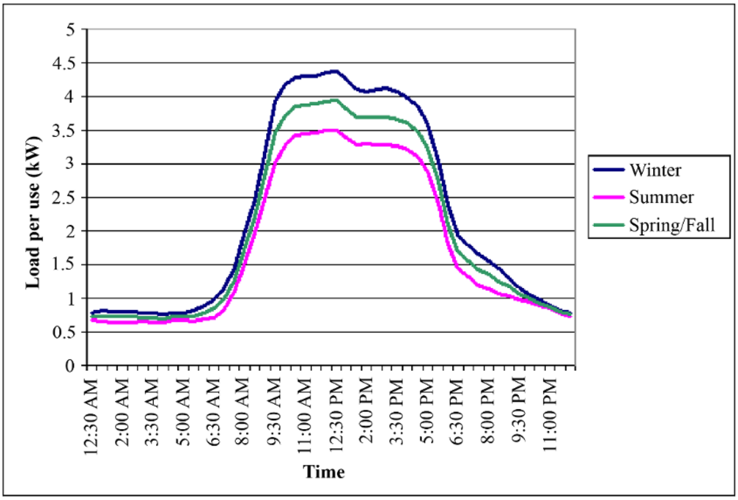

Figure 1.4. *Typical profiles for tertiary and small-scale manufacturing consumers (RTE)*

Figure 1.5 shows the power consumption profile for a large supermarket over the course of a week. The subscribed power in the example shown is 1200 kW. This is a non-optimized value, ensuring that this limit is never exceeded; going over this threshold would mean paying expensive penalties to the network operator. The addition of local storage and production would enable the optimization of subscribed power, reducing the cost of energy drawn from the grid.

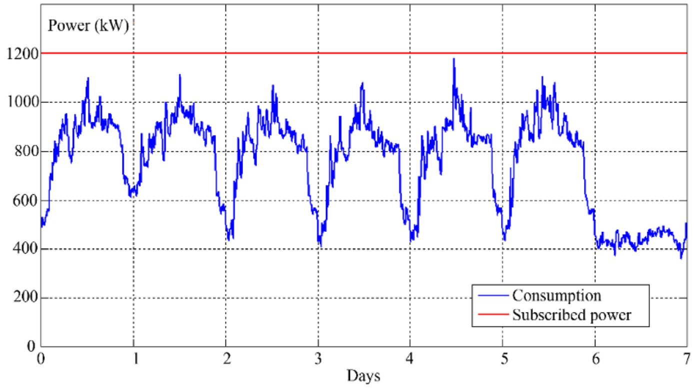

Figure 1.5. *Power consumption profile for a large supermarket over the course of a week*