Smart Grid Optimised Buildings with Energy Storage

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Introduction

Buildings have always been responsible for a significant amount of the global energy consumption and the consequent carbon emissions. There is an increasing number of literature referring to buildings and their characteristics, given the present trends towards energy efficiency and sustainability. Different definitions can be found but they all embrace the same basic concepts, especially intelligence and sustainability, while their purpose is to achieve the optimal combination of comfort level and energy consumption. The current strategy behind improving energy efficiency is to consume lower levels of energy for the different functions of the building, without compromising the comfort and satisfaction of the residents. Therefore, the majority of the projects and research have followed an ad hoc approach, covering only existing buildings, without a concrete decision-making process [1]. In contrast, Smart Grid Optimised Buildings (SGOBs) differ from Smart and Sustainable Buildings, regarding their aim and objectives. Conceptually, they must have an active interaction with the energy network through responses to dynamic electricity prices and carbon emissions, similarly to Active Buildings [2].

Research Hypothesis

- Building design and the incorporated energy systems can be techno-economically optimised for the needs of the Smart Grid.
- The energy storage characteristics will play a crucial role in ensuring that buildings function as an effective sub-system of the Smart Grid environment.

Aim

- To define SGOBs, as a component of the smart grid infrastructure in a manner that allows its attributes of generation, storage and consumption to be assessed as a competing component of energy infrastructure.
- To define at what scale, using what technology and distributed in what manner should energy storage be located in buildings.

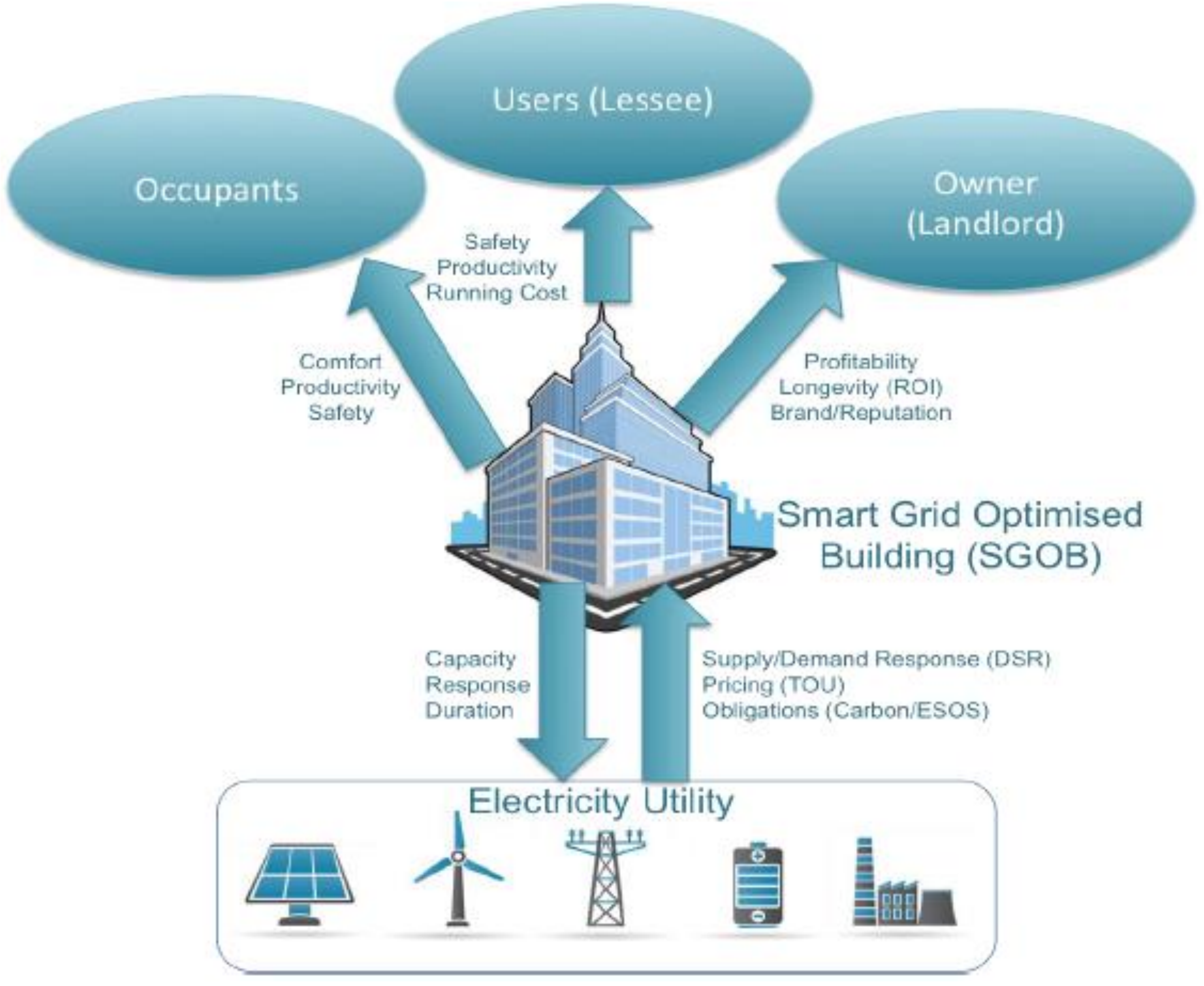


Figure 1 – Relationships between SGOB, occupants and the electricity provider

SGOB Definition

- A SGOB can be thought of as meeting its service obligations to its occupants and minimising its operational cost and footprint to its owner while actively engaging with the electricity provider, enabling best use of the resources available (Figure 1).
- Receiving information and prompts from the grid network, the SGOB can determine the appropriate level of participation based on the intelligence of the embedded systems and the service obligations it has to its stakeholder.

SGOB Characteristics

The functional characteristics of a building designed to work as an edge system within a wider smart grid to achieve the overall goal of addressing the energy trilemma are:

- The capability of the building to increase or reduce grid-connected load on demand
- The acceptability of the impact of reducing or increasing grid derived load.
- The notice required to make a change to grid derived load.
- The response time (delay) between confirmed request and change being evident.

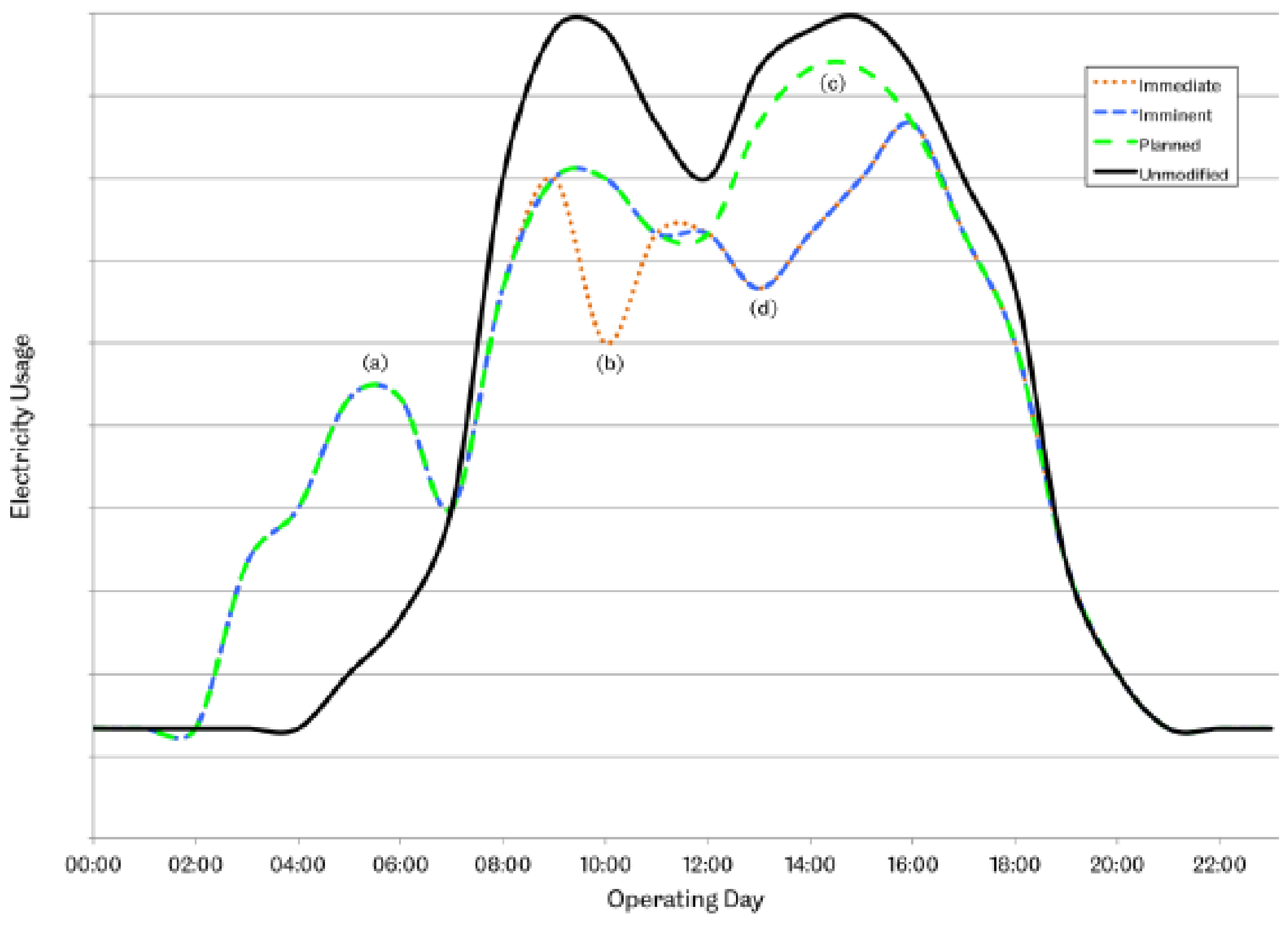
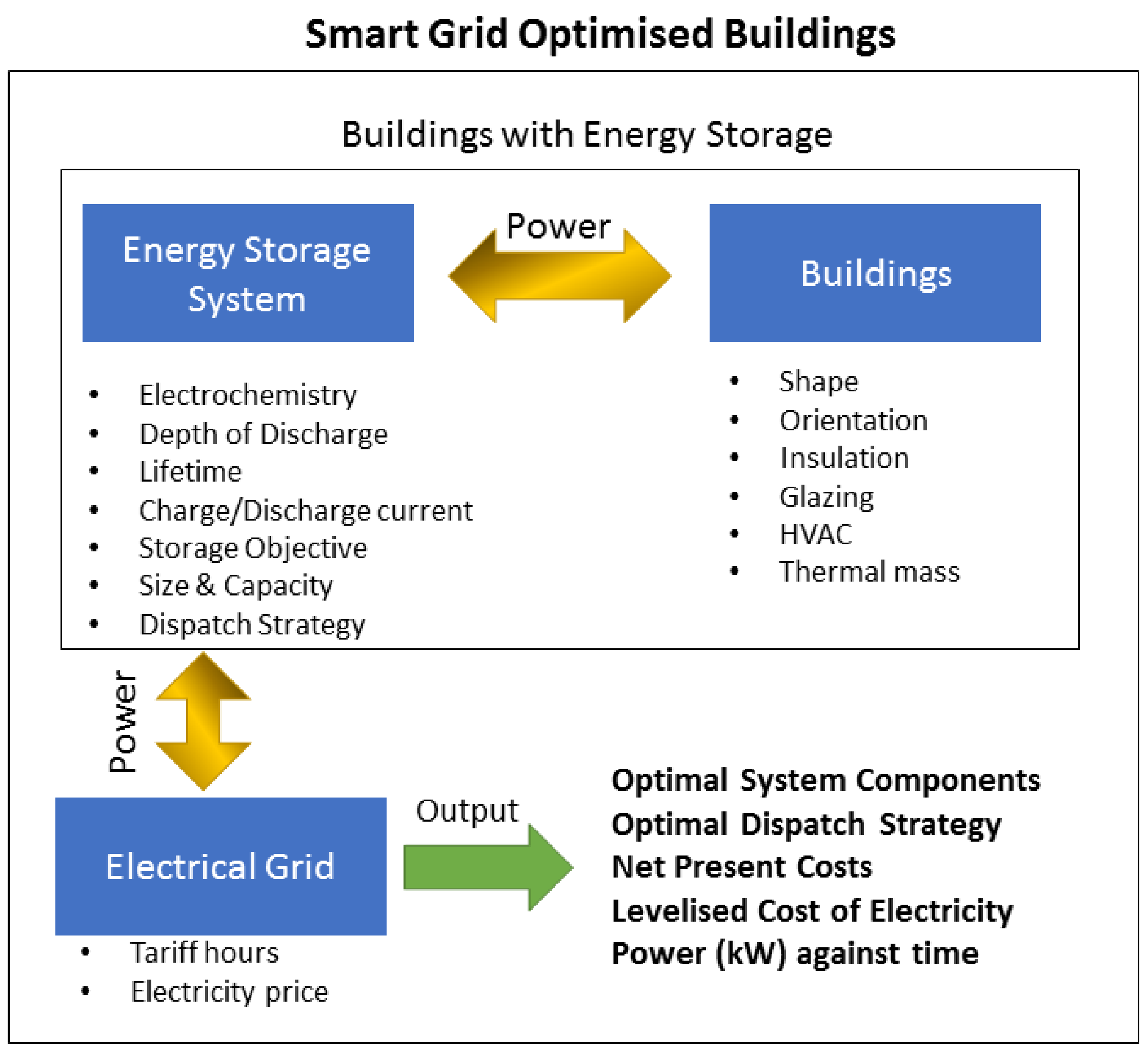


Figure 2 – Electricity usage and effect of Smart Grid requests for modification

The requests received from the Smart Grid in order to provide such services (Figure 2) can be broken down temporally as follows:

- Planned (day): largely informational, this data allows the grid to request that suitably equipped buildings prepare themselves a day ahead; for instance, to maximise the use of its passive systems to store or release energy.
- Imminent (minutes/hours): communication intended to enable the management of demand when unexpected changes in consumption occur, during the daily usage cycle.
- Immediate (seconds): urgent request to modify consumption in response to unplanned and unexpected incidents, such as generating equipment or transmission system failure.

Methodology & Results


Smart Grid Optimised Buildings

Buildings with Energy Storage

Energy Storage System

Power

Buildings

- Electrochemistry
- Depth of Discharge
- Lifetime
- Charge/Discharge current
- Storage Objective
- Size & Capacity
- Dispatch Strategy

- Shape
- Orientation
- Insulation
- Glazing
- HVAC
- Thermal mass

Power

Electrical Grid

- Tariff hours
- Electricity price

Output

Optimal System Components
Optimal Dispatch Strategy
Net Present Costs
Levelised Cost of Electricity
Power (kW) against time

Figure 3 – Methodology for Smart Grid Optimised Buildings

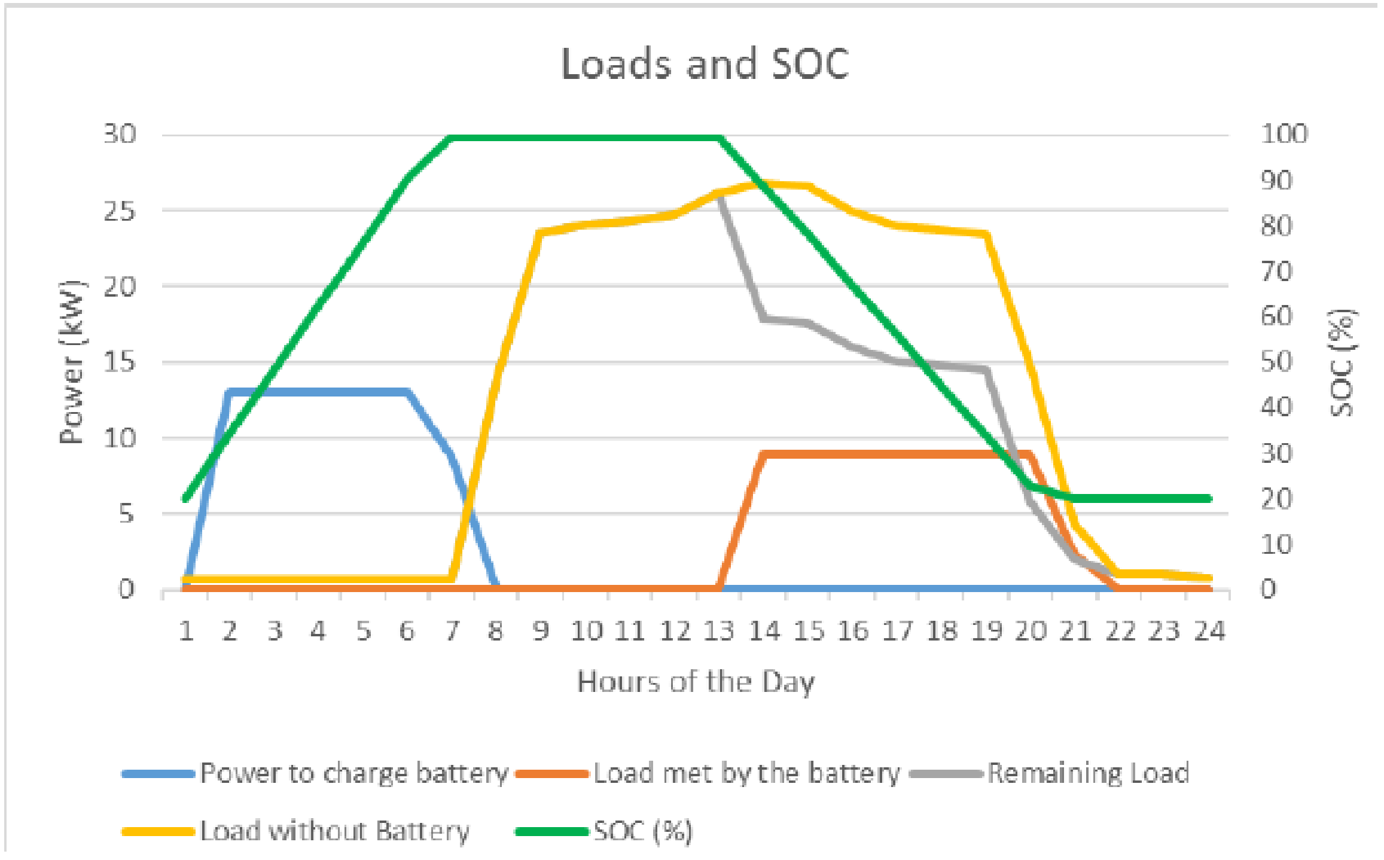


Figure 4 – Battery Storage providing arbitrage in a commercial building. System: 14 LG Chem (RESU-6.4) batteries in series. Total Capacity 89.6 kWh, Maximum Discharge Power = 9 kW, DOD = 80%.

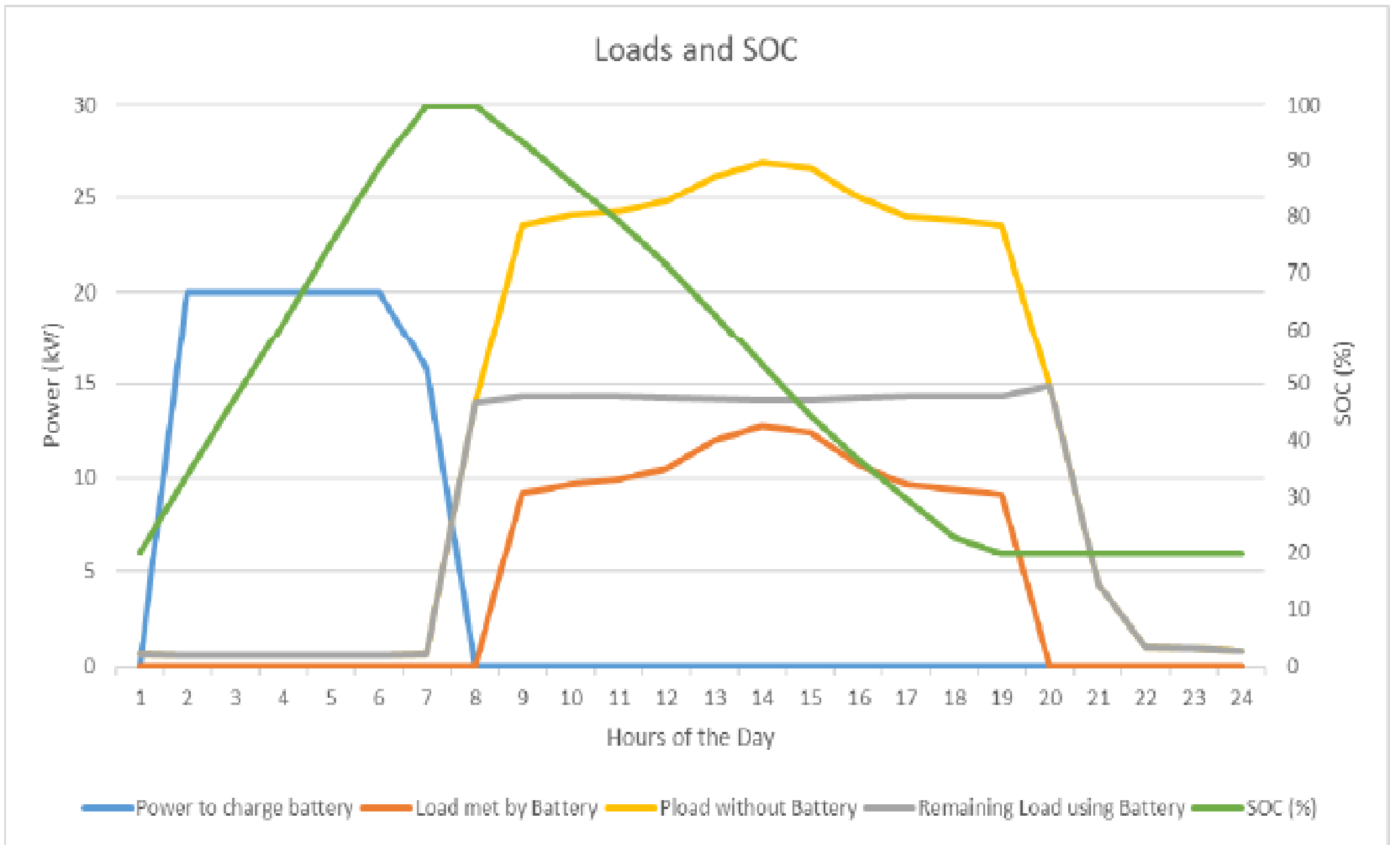


Figure 5 – Battery storage providing load leveling (P_{limit} = 15 kW). System: 22 LG Chem (RESU-6.4) batteries in series. Total Capacity 140.8 kWh, DOD =80%.

Discussion & Conclusions

- Figures 4 and Figure 5 refer to the daily average electrical load of a reference commercial building, built in DesignBuilder.
- Heating is provided by a natural gas boiler and therefore thermal loads are not considered.
- Battery storage covers 40% of the peak loads in the arbitrage case. In order for the scheme to be viable, the price of peak electricity has to increase by 100%.
- Both arbitrage and load leveling are not currently cost-effective due to the capital cost of the batteries.
- Financial motives from the Network Operators are needed.

[1] D. Ürge-Vorsatz, N. Eyre, P. Graham, D. Harvey, E. Hertwich, Y. Jiang, C. Kornevall, M. Majumdar, J. E. McMahon, S. Mirasgedis, S. Murakami, A. Novikova, K. Janda, O. Masera, M. McNeil, K. Petrichenko, and S. Tirado Herrero, "Energy End-Use: Buildings. Global Energy Assessment: Toward a Sustainable Future", 2012.

[2] M. B. Bulut, M. Odlare, P. Stigson, F. Wallin, and I. Vassileva, "Active buildings in smart grids - Exploring the views of the Swedish energy and buildings sectors," *Energy Build.*, vol. 117, pp. 185–198, 2016.