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Designing smart, resilient cities for all

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Executive summary

Akademiska Hus AB, which owns the university college buildings for the Swedish State by working together with other local players in Umea develop neighborhoods of the University city area in the smart city project RUGGEDISED. The goal is also to reduce CO^2 emissions in the city of Umea by involving students, personal and other people in the university area.

To reduce energy consumption and CO^2 emissions several solutions have been tested and developed in the University area of Umea. This report describes the implementation of Smart Solution 'E-charging hub & charging infrastructure' in the University area of Umea. Akademiska Hus has installed a solar powered charging infrastructure at the campus of Umea and combined it with the storage battery. The implementation of the Smart Solution also includes providing a battery facility control which enables the consumer to optimising battery charge or discharge.

In a building the loads are variable and it is actually the peak loads that determine the specifications of the system. The peak electricity are usually generated with fossil fuel and are used by electricity grid companies to dimension the electricalgrid capacity. This indicates the need to reduce electricity peak load. Akademiska Hus will do this through the charging hub and the charging control.

The installation of the facility got completed in September 2019 and an analysis tool has also been developed in the purpose to simulate, develope and optimise the electricity production and consumption in the building. The challenge is to find the right balance between the loads and the battery.

Another goal with this project is to be able to draw scalable conclusions. Akademiska hus is aiming to be able to use the conclusions from this experiment for upscaling in other buildings at the university area in the future. By finding keyparameters and using smart measures from this facility such as the size of the battery and moving the loads optimaly Akademsika Hus will be able to draw scalable conclusions and dimension other buildings in a smart way.

VCC, the owner of hospital in Umea, has also built a supercharger for electric taxis in the hospital area. The overall purpose with the supercharger is reducing the CO^2 emissions in the city of Umea.
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The campus and hospital area in Umea holds a large number of work place parking spaces and currently has a limited number of public E-charging stations, which can be a problem for electric car owners. By installing E-vehicle charging facilities at this area gives more opportunities to the personnel and the visitors to choose and charge e-cars and also send a clear and visible massage about the importance of the reducing the environmental impact to the community.

Contents

1 Introduction

1.1 Background

Akademiska Hus AB, which owns the university college buildings for the Swedish State by working together with other local players in Umea develop neighborhoods of the University city area in the smart city project RUGGEDISED. The goal is also to reduce CO^2 emissions in the city of Umea by involving students, personal and other people in the university area.

In purpose to reduce energy consumption and CO^2 emissions several solutions have been tested and developed in the University area of Umea. This report describes the implementation of E-charging hub & charging infrastructure in the University area of Umea.

In order to encourage the use of electric mobility, Akademiska hus has installed a new facility at the campus area in Umea for charging of electric cars powered by renewable energy sources. Normalbuildings have a variable energy loadsand it is actually the peak loads that determine the specifications of the system.
The idea is to reduce the electricity peak loads through this e-charging hubthe battery facility control.

Based on the goal of increasing the reduction in emissions in the area, VCC (the owner of the hospital in Umea) has also built a central for electric car charging. In total, five charging points have been installed in a very attractive location just at the entrance to the regional hospital.

Peak electricity demands are usually met by fossil fuel generations such as oil and gas; hence, peak demand hours are more carbon intensive than off-peak hours. Peak power are used by electricity grid companies to dimension the electricial grid capacity. This indicates the need to reduce electricity demand, in particular peak demand, which has caught the attention. This report highlights the challenges facing reducing electricity peak load, and how to shave the peak load by applying the consumption patterns in the property.

1.2 Purpose

The purpose of this solution is to find a smarter energy system solution with lower climate impact by integrating grid owners and involving end users to reach the objectives of a climate neutral energy system.
The mail goal is to even out the power consumption and also find an optimal distribution between building loads, battery storage and solar panels (such as identifying the potential time frame for charging e-cars without peaking at the power outlet).

The experience from the charging hub will also lead to make assessments of the size of the battery plant that is optimal for different types of properties. The idea is to be able to draw conclusions on how use patterns and loads affect the need for battery storage.

The project also includes providing a battery facility control, in order to control and adjust in which positions the battery system should be charged or discharged. The challenge for this Smart Solution is to find optimal battery charge or discharge strategies.

Overall purpose has also been to see if the emissions in the area can be lowered by giving the population the means to make their travel more environmentally friendly. For this solution, the target was to open up the area where the natural companies that install EV-chargers in the region don't have the possibility to install regarding land owning and electric grid. At the hospital the possibility has been opened for taxis with electric vehicles to charge while waiting for patients as well as patients who can charge their car while making their visit.

2 Methodology

Akademiska Hus has installed a solar powered charging infrastructure for electric cars at the campus of Umea to generate electricity by solar panels and use the generated electricity for charging of electric cars. The charging infrastructure has been completed with a battery facility to be able to storage the electricity and in the purpose to shave the peak demand. The purpose of this solution is to examine a possible charging strategy without peaking the electricity demand.

2.1 General description

Figure 1 presents the combined PV and battery system connected to the electricity grid at the Campus of Umea. It also includes both battery and PV inverters which are necessary to control the different power flows which can occur, such as PV to load, PV to battery, PV to grid and grid to load. The power flows can shift in both size and direction, depending on size of load and amount PV production.

Whenever the sun shines, the solar cells generate electricity. The solar panels collect energy from the sun and turn it into Direct current, DC electricity. The DC electricity will be passed through an inverter, Energy Hub and convert to the alternating current , AC electricity that can be used by the electrical loads in the property. The power produced by the solar electric system will first be consumed by the electrical loads which is in operation in the building, Such as HVAC-unit, building electricity and lighting. When the solar panels produce more electricity than the need, the excess solar electricity goes towards charging the battery for use later. When the battery is fully charged the electricity will be sending back to the grid

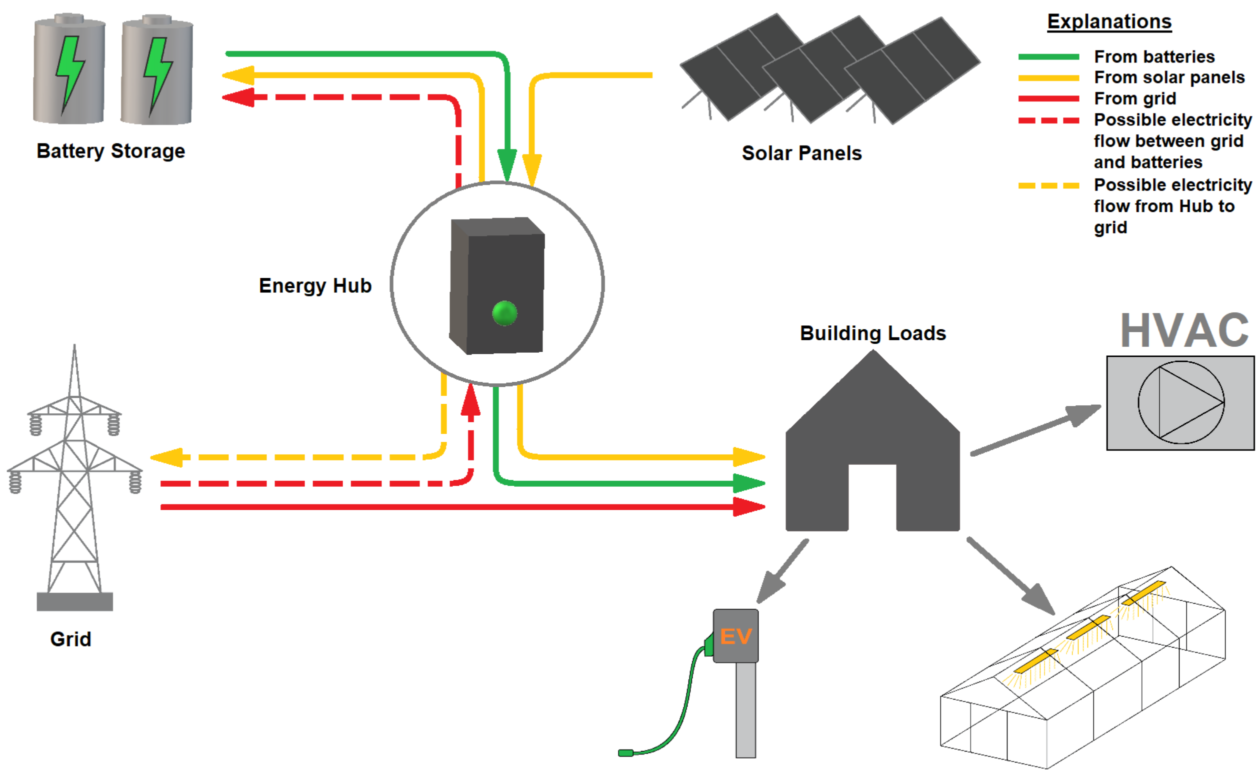

Figure 1. The combined PV and battery system connected to the electricity grid at the campus of Umea.

2.1.1 Main components

The E-charging infrastructure at the Campus of Umea consists of the main components as following:

- Energy-hub
- Solar string optimizer
- Energy storage battery
- Energy storage optimizer
- Electric car chargers
- Electricity meter

2.2 Description of components

2.2.1 Solar Plant

The facility consists of 84 solar panels where each provides peak power of 310 W, see Figure 2. The total installed power of the PV plant is 26 kW. Solar panels are connected together and distributed into the 5 strings. Each string is linked to a separate solar string optimizer which are located on connecting house facade outdoors, see Figure 3. The function of solar optimizer is increasing the energy output from each panel independently.

Figure 2. Installed solar panels at the campus of Umea.

Figure 3. Installed solar optimizer at the campus of Umea.

2.2.2 Battery facility

In the property, a battery storage has been installed with a peak power of 22 kW and is associated with an Energy Storage Optimizer which optimizes the energy flow to and from the battery, see Figure 4. Solar bettery work by storing energy produced by the solar panels and storing it as for later use. For instancethe electricity generated during the summer will be stored in the battery and used under the winter when the electricity needs are more. The storage battery contains also a system called BMS (Battery Management System) that is preventing the battery from overcharging or deep-discharding. The system also enables the user to find an optimal battery charge or discharge strategy.

The battery storage is connected to an Energy Hub with a peak power of 28 kW, see Figure 5. The Energy Hub acts as a bridge between the utility AC electricity grid and a local DC electricity nanogrid within the building where the solar cells, batteries and loads are conected. The energy Hub (Inverter) converts the DC electricity produced by the solar panels into the AC electricity, which can then be used by the property.

Figure 4. Installed battery storage at the campus of Umea.

Figure 5. Installed Energy Hub at the campus of Umea.

2.2.3 Electric car chargers

A number of electric car chargers are installed and connected to the facility see Figure 6 . The charging of e-cars depend on the amount of electricity generated by solar panels and the electricity consumption in the property. The challenge is to find out a charging strategy without significant impacts on power system like peak load.

Figure 6. Electric car chargers at campus of Umea.

At the e veichle charging area at the university hospital five charging points have also been installed. Four of themare semi-fast chargers with type 2 connection and 22 kW delivery, fabricat Schender Evlink. The fastcharger is delivered by Evbox with CSS connection. The Evbox charger is designed to deliver 50 kW but with the possibility to upgrade to even faster if needed as well as an integrated battery storage. The electric cable and station can deliver 250 Ampere, see Figure 7

Figure 7. Picture showing Evbox installation and Evlink installation outside the hospital entrance.

2.2.4 Electricity meter

There are various loads in the current building such as building electricity, greenhouse lighting, HVAC units and e-cars charging. Each load has a separate energy meter in order to measure and record electricity usage by the load in the property separately. The purpose is to get consumption patterns and learn how these affect the building and the peak load.

2.2.5 Web portal

In addition to the ability to view the physical display at the Energy Hub, it is possible to monitor the facility through a web portal. The web portal enables to track the electricity production and to see the generated electricity by solar panels in the real time and the percentage of electricity which have been used directly in the property, stored in the battery or feed into the grid if there is any surplus electricity, see Figure 8 .

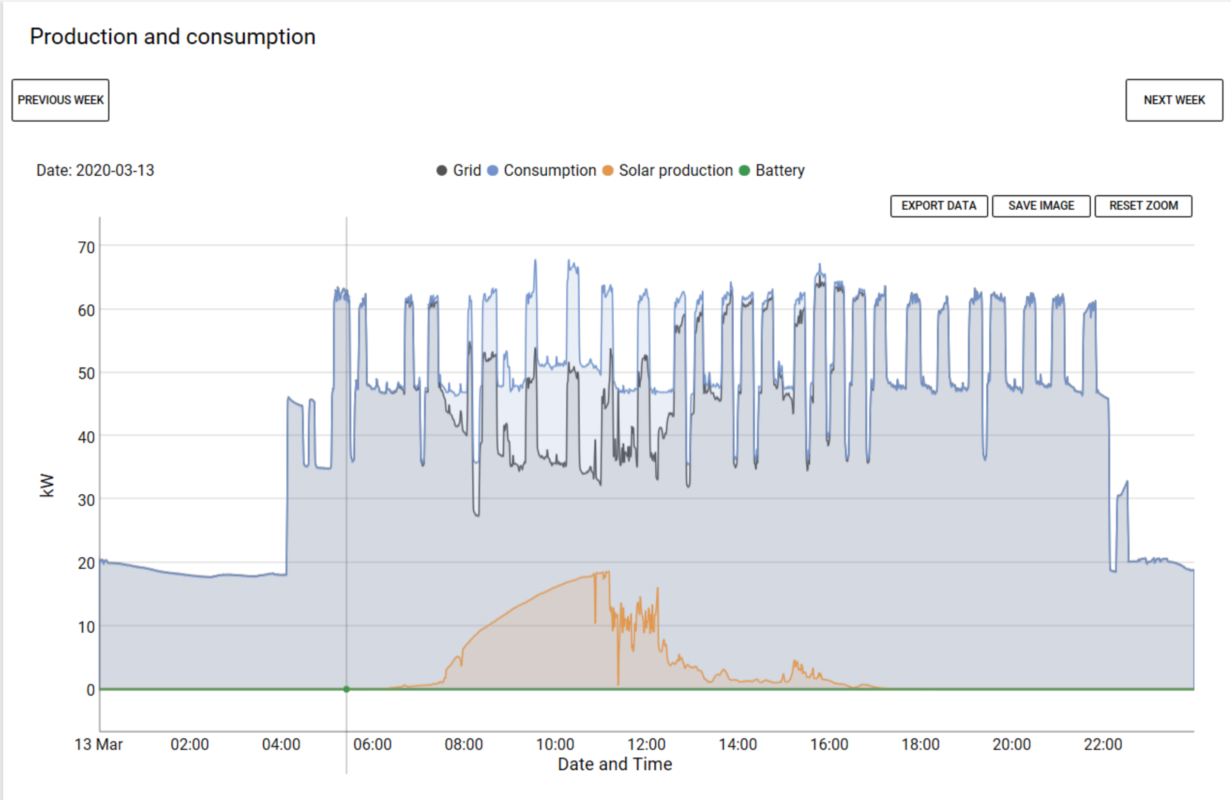

Figure 8. Production and consumption in the property, Ferroamp web portal.

3 Monitoring user

3.1 Analysis tools

The challenge is to design a control scheme that detects the peaks on time and fully exploiting the capacity of the energy storage system. This will lead to the peak shaving. An analysis tool has been developed as a control scheme and in the purpose to simulate, develop and optimize the electricity production and consumption in the property. The power data for individual consumers as well as the total electricity consumption of the property over a day import from the web portal to the tool. The time for the peak demand for the selected day and how it is distributed to the respective consumers also presents in the data table.

In the current building there are different electrical loads such as HVAC-unit, greenhouse lighting, EV-charging and the building electricity. The tool has been completed with a theoretical consumer named user assigned consumer. Since the facility will be upscaled in the future to other buildings with different loads there must be opportunity to study the effect of a theoretical consumer on the peak load. Each electricity load in the building presents as a percentage or a ratio of the total consumption in kW.

With the help of scale factor, the various consumers could be scaled up or down by the user to simulate a larger or smaller plant, see Figure 9. As the figure presents the total consumption is 57,3 kW and the power peak occurs at 8 am at this example.

Consumer	Scale factor	Power at total peak (kW)	Part of total consumption (%)	Time of day (h:min)
HVAC-unit	1	15,0	26,2%	
Greenhouse lighting	1	25,0	43,6%	
EV charging	1	10,0	17,5%	
Building electricity	1	13,9	24,3%	
User assigned consumer	1	0,0	0,0%	
Total consumption		57,3	100,0%	08:00:00

Producer/Consumer	Scale factor	Power at total peak (kW)	Part of total consumption (%)
Batteries	1	0,0	0,0%
Solar panels	1	-6,6	11,5%

Figure 9. Input and output power data for the current building.

The statistical data can also be graphically presented in a power diagram. Each graph represents the power consumption for individual consumer, power output of solar panels, power stored in the battery and the total electricity consumption in the building over a day. The advantage of the graphs is providing an overview of the consumptions and productions pattern and their impact to the total power consumption and the peak load. The consumer will be able to analyse the electricity consumption and production and by changing the consumers behaviour control the electricity consumption during a time, see Figure 10. This will contribute to the peak load shaving.

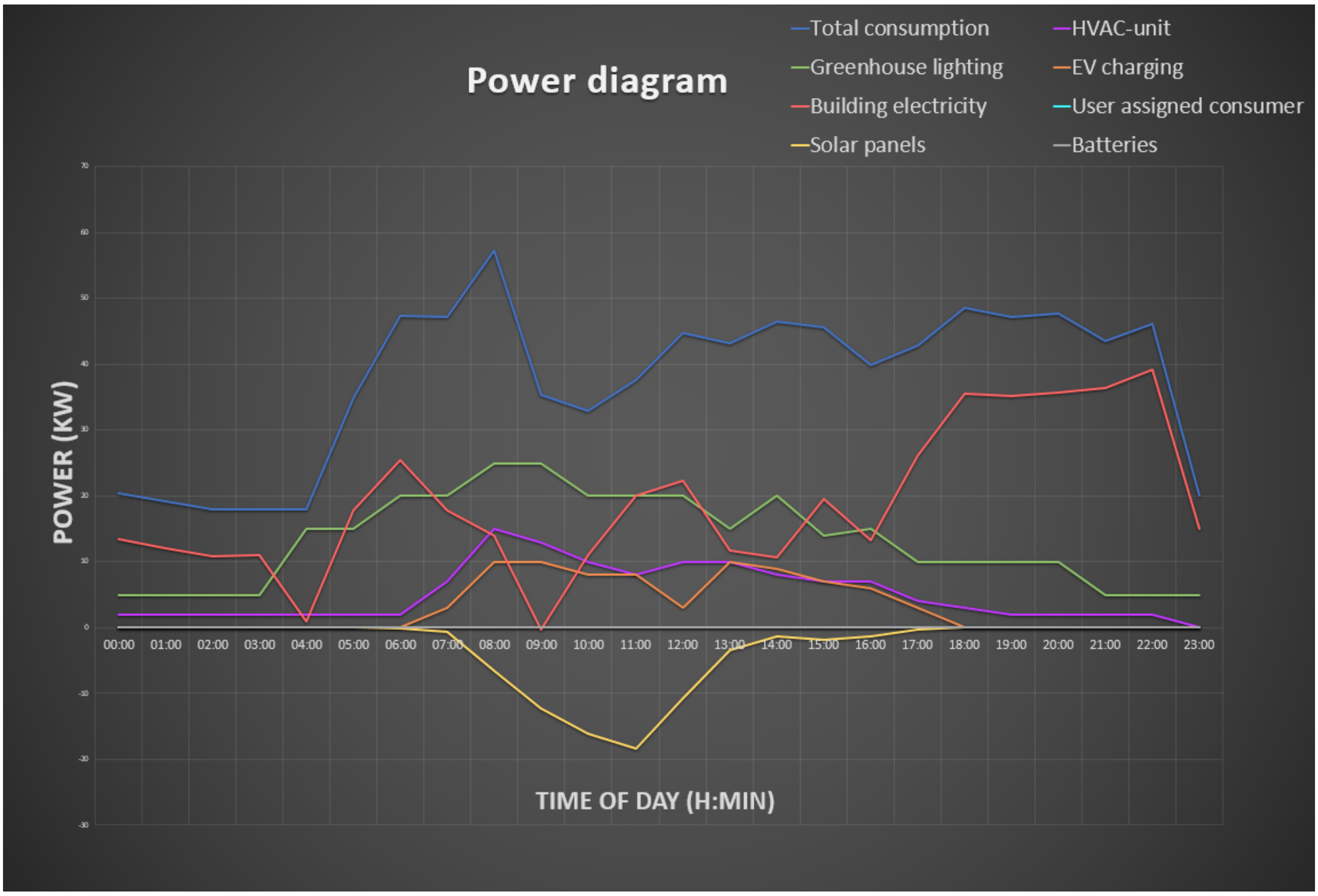

Figure 10. Electricity consumption, production and peak load for the current building.

3.2 Filtration and shifting

As a purpose of this solution is to shave the peak load, the consumer should be able to monitor and control the power usage of various loads in the building in a more advanced way. With peak shaving, the consumer reduces power consumption for a short period of time to avoid a spike in consumption. The filtration, offset and reset tools enable the consumer to manage the peak loads.

By using the filtration tool, the consumer will be able to filtrate and study a specific load and its power curve during a certain time. The load shifting helps the consumer to move the power curve forward or backward in time. The function refers to a short time reduction in electricity consumption followed by decreasing the consumption when the total consumption is high. As an example, by offsetting the EV-charging forward by one hour the total consumption will be reduced to 51,6 kW and the peak load occurs at 6 pm, see Figure 11, Figure 12 and Figure 13.

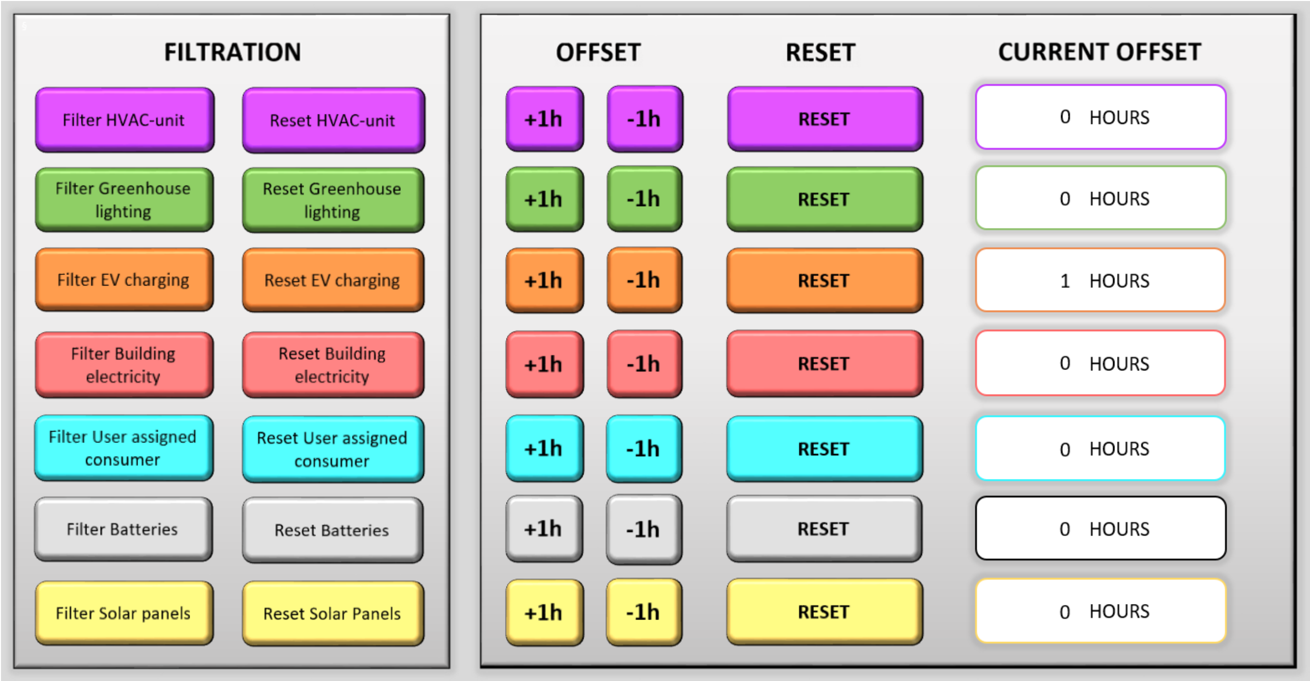

Figure 11. Offsetting the EV-charging forward by 1 hour.

Consumer	Scale factor	Power at total peak (kW)	Part of total consumption (%)	Time of day (h:min)
HVAC-unit	1	3,0	5,8%	
Greenhouse lighting	1	10,0	19,4%	
EV charging	1	3,0	5,8%	
Building electricity	1	35,6	69,0%	
User assigned consumer	1	0,0	0,0%	
Total consumption		51,6	100,0%	18:00:00

Producer/Consumer	Scale factor	Power at total peak (kW)	Part of total consumption (%)
Batteries	1	0,0	0,0%
Solar panels	1	0,0	0,0%

Figure 12. Reducing the total consumption and changing the time for the peak load after offsetting the EV-charging by 1 hour.

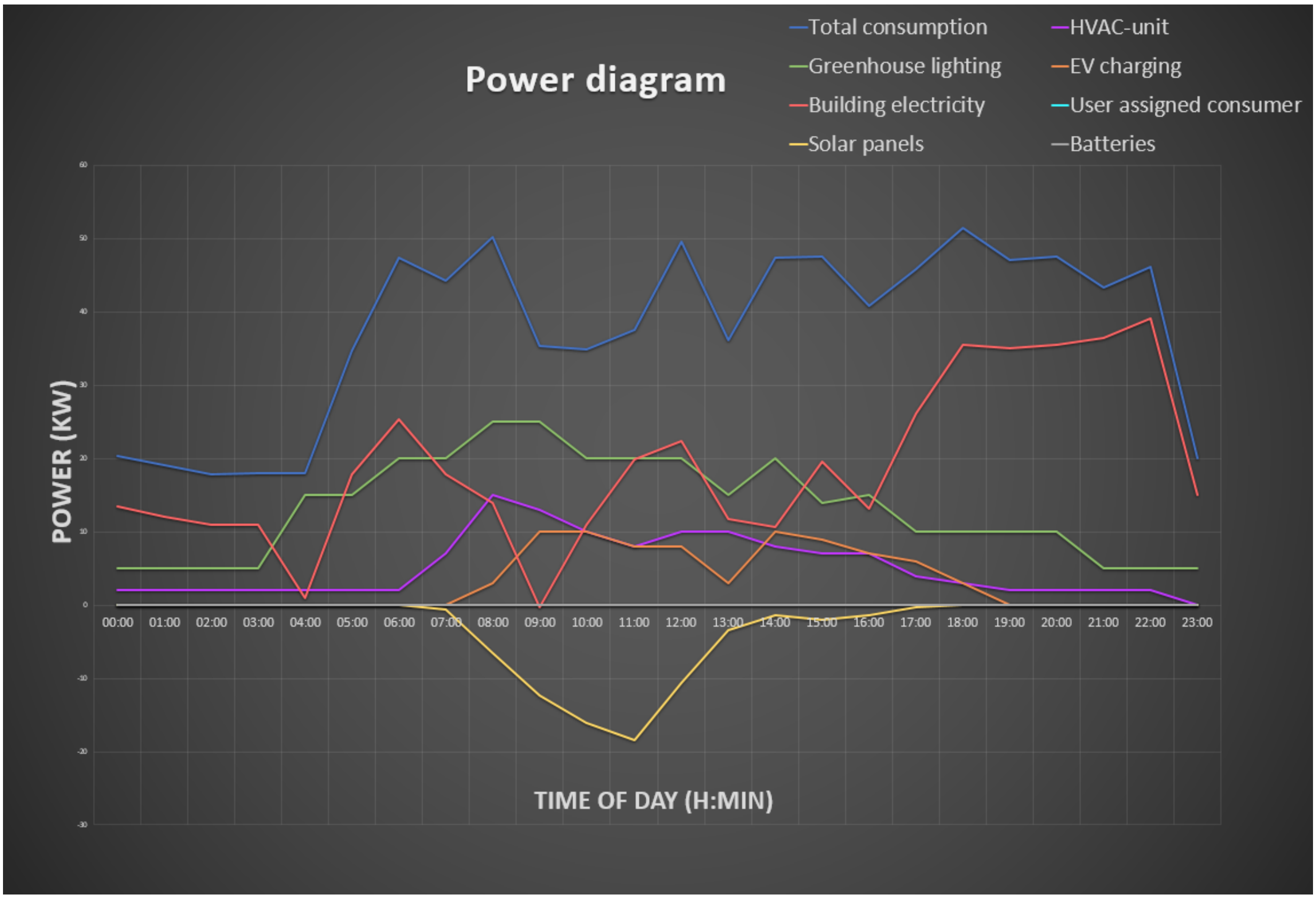

Figure 13. Power diagram and peak load after offsetting the EV-charging by 1 hour.

4 Replication

One goal with this project is to be able to draw scalable conclusions and replicate the solution in other buildings at the university area. Buildings with high and short power peaks are more suitable for replication of this specific solution.

.Key parameters such as finding optimal charging/discharging strategies for battery storage, optimal type and capacity of the battery and the size of the PV plant are essential and importatnt for Akademsika Hus to simply replicate the solution in the future. The analysis tool are useful at this system and can be simply connected to more properties and PV plants in the future.

The experiences from this solution and knowing how the electricity supply can be optimized with charging hubs in the properties will lead Akademiska Hus to providing more houses with the same facility and thus reach another step towards using only renewable energy sources.

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