Comparison of the Simulated and Measured Performance of the PV Plant of Austria's Largest (Plus-)Plus-Energy Office Building

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Abstract

The (Plus-)Plus-Energy Office High-Rise Building near the centre of Vienna is a highly energy-efficient office tower block that is designed according to a net-zero energy concept. The main component of the net-zero energy concept is the building's PV plant. An extensive energy monitoring system is integrated into the building. As it also logs the electricity production of the plant's 19 PV inverters, it allows for a more detailed analysis of the PV electricity production. In this research the monitoring data of the PV plant that was obtained during 2018 is analysed. The design performance of different parts of the plant is contrasted with the monitored performance. Moreover, the building's PV self-consumption is analysed. Even though there were several inverter faults during the years, the PV plant generally achieved its design performance. Due to the fact that the building's consumption exceeds the design consumption, the building's PV self-consumption is significantly increased.

Keywords: university campus, office building, building integrated photovoltaic, performance monitoring, coverage of self-consumption

1. Introduction

Net-zero energy building concepts are one of the key elements necessary to reduce the energy consumption in the building sector and to achieve the EU's climate goals (European Parliament, 2018). The design concept of TU Wien's (Plus-)Plus-Energy Office High-Rise Building at the University Campus "Getreidemarkt" proves that it is theoretically possible to develop even high-rise buildings as net-zero energy buildings (Schöberl et al., 2014). One important component for achieving the net-zero energy concept is the building's PV plant.

In order to enable the assessment of the real building performance, the (Plus-)Plus-Energy Office High-Rise Building is equipped with an extensive energy monitoring system. Further, this system is used to aid in commissioning and optimising the building. Previously published results of the building's energy monitoring showed the difference between the building's theoretical design performance and its real performance (David et al., 2017, David and Bednar, 2020). Even though several of the planned energy reduction potentials could be realised, some could not be realised and due to various reasons, such more IT equipment in the offices than planned, the real energy consumption exceeds the design value. However, the electricity production of the building's PV plant generally achieved its design performance, although there were several inverter faults during the years (David et al., 2017; David and Bednar, 2020).

There are several papers presenting different surveys on the monitoring data of building integrated PV (BIPV) systems (Klugmann-Radziemska and Rudnicka, 2020; Imenes 2016). Some studies do also discuss the comparison of the measured and the simulated performances of BIPV systems (Bellazzi et al., 2018; Maturi et al., 2010). All these papers have in common that they only focus on the electricity yield of the entire PV system. As in case of the (Plus-)Plus-Energy Office High-Rise Building there is monitoring data available for each of the inverters, we analyse in our research the specific annual electricity yield of different parts of the PV plant.

Since one of the main aspects of the building's energy concepts is that in the yearly energy balance the PV electricity production should cover the building's energy consumption, this paper also addresses the building's self-consumption. As the two main options to increase the self-consumption are (battery) energy storages and demand side management (Luthander et al., 2015), the maximum electricity surplus that can be expected to occur during the course of a year is calculated. Further, we investigate the absolute minimum battery size that would be

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necessary for the building to be self-sufficient in terms of electricity consumption, and the impact of different battery sizes on the self-consumption.

For these purposes, we used the data from 2018 for the analyses conducted in this paper. The data forms a good basis since 2018 was the first year after building's optimisation and there are no gaps in the monitoring data. More recent data could currently not be used since it is not processed yet. The main reasons for that are that the official monitoring and optimisation project ended after 2018 and that the data processing involves several labour-intensive tasks, e.g., filling gaps in the data with manually extracted data from the building operation system.

Since the (Plus-)Plus-Energy Office High-Rise Building itself is only a part of a larger building complex, its system boundaries also had to be considered during all analyses (David et al., 2017). For instance, only energy consumption that occurred inside the boundaries was part of the building's energy balance. The same principle had to be applied to the electricity production by the building's PV plant – i.e., the electricity supplied by PV modules that are outside the system boundary had to be excluded from the energy balance. As eight of the high-rise's ten floors equipped with building integrated PV (BIPV), the electricity production of the entire PV was multiplied by the factor 0.8 to calculate the production that can be considered to be "inside the system boundary". In Section 4 all results that are marked with "boundary zone PV" refer to this electricity production "inside the system boundary". Results without mark or that are marked with "entire PV plant" refer to the electricity production of the entire PV plant – i.e., without any scaling.

2. Specifications of the PV plant

In this section, we give an overview of the specifications of the PV plant of the TU Wien's (Plus-)Plus-Energy Office High-Rise Building.

Fig. 1 gives a general view over the four parts of the building's PV plant: (i) southwest roof, (ii) southwest façade, (iii) southeast PV insulating glass, and (iv) southeast façade.

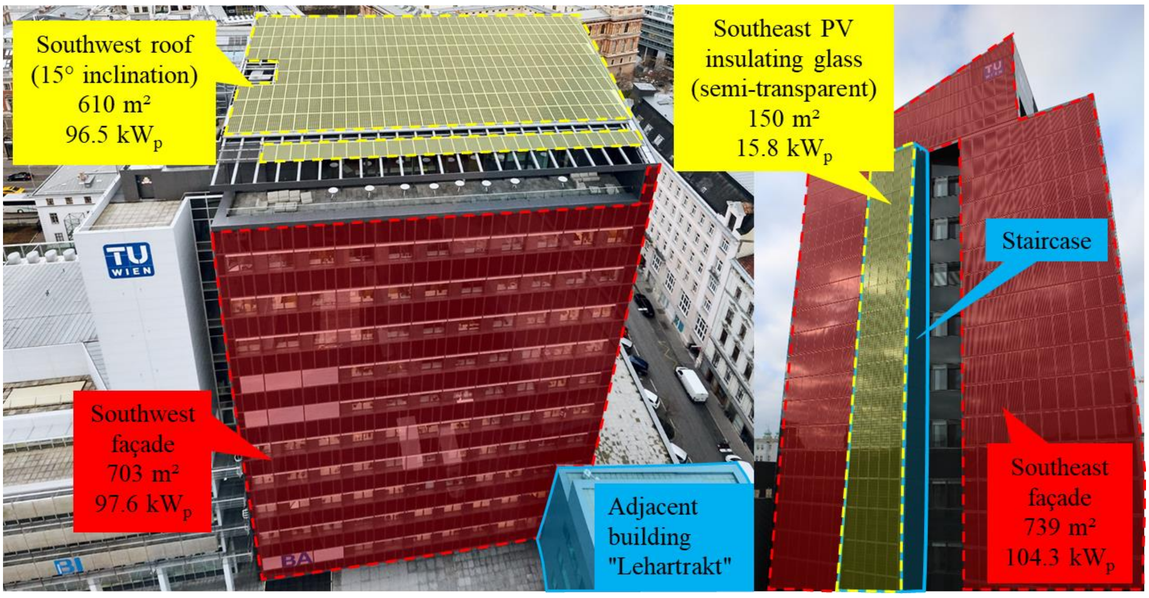

Fig. 1: Overview of the parts of the (Plus)-Plus-Energy Office High-Rise Building's PV plant

The building is the only high-rise building in the vicinity, i.e., there is almost no shading from the surrounding buildings. Just the adjacent TU Wien building "Lehartrakt" sometimes casts a shadow on the lower parts of the PV modules integrated into the southwest façade. Another reason for partial shading is the building's staircase which is protruding from the rest of the southeast façade. This leads to shading of parts of the southeast façade's left side in the morning. The part of the PV plant that is totally free of shading is the PV system on the roof.

Fig. 2 illustrates the schematic overview of this PV system on the building's roof. The areas marked with A_i in Fig. 2 highlight the different sub-surfaces of the PV system. All modules of the same sub-surface are connected to the same inverter I_i. The different colouring indicates different PV module types.

As it can be seen in Fig. 2, there are two gaps in the layout: (i) one on the left side of the PV system and (ii) one between the last and the second last row at the bottom side. The reason for (i) is that this is the location of the outlet of the ventilation shaft of the building's night ventilation system. The reason for (ii) is that this gap is needed in case of snowfall. If snow accumulates on the PV system on the roof, it must be ensured that this snow does not slide into the inner courtyard. Due to the height of the building, this snowfall might inflict serious damage to passers-by, items or infrastructure. Thus, the PV system on the roof was designed accordingly.

The PV plant on the roof has a 15° inclination towards southwest. Below the modules there is a hollow space between the real, flat roof of the building and the surface that is formed by the PV modules. All modules are standard monocrystalline modules with glass on the frontside and a plastic layer on the backside.

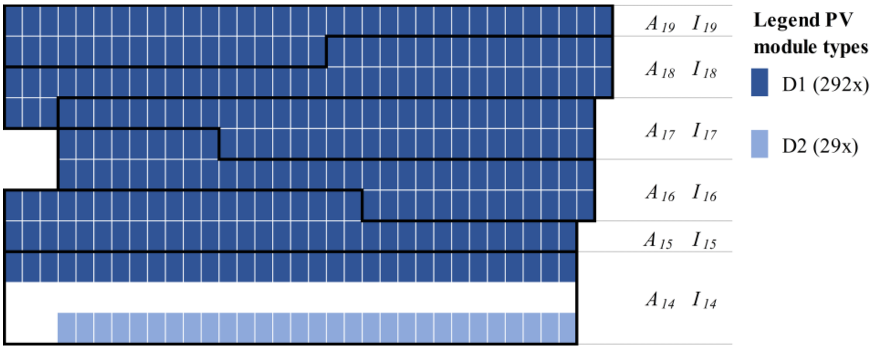

Fig. 2: Schematic representation of the PV system on the roof

Fig. 3 shows the schematic overview of the PV system integrated into the building's southwest façade in the same manner as Fig. 2. In the southwest façade the PV modules are installed in the parapet area of each floor – the only exceptions being single modules on the left and right edges of the façade. The gaps between the PV modules indicate the location of the building's windows. The gap in the right bottom corner is caused due to the connection to the adjacent building "Lehartrakt". All of the southwest façade's PV modules are monocrystalline double glass modules.

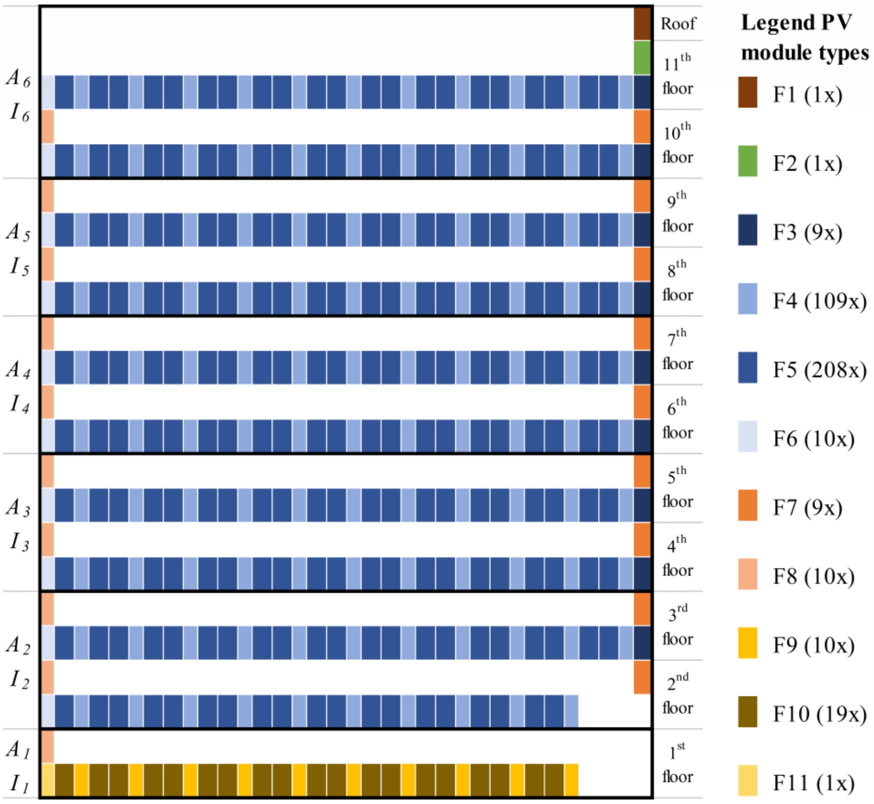

Fig. 3: Schematic representation of the PV system integrated into the southwest façade

The schematic overview of the PV system integrated into the southeast façade is displayed in Fig. 4 in the same manner as the schematics in Fig. 2 and Fig. 3. It shows that almost the entire southeast façade is equipped with PV modules.

Modules with the prefix "F" are monocrystalline double glass modules and modules with the prefix "S" are monocrystalline PV insulating glass modules. As can be seen in Fig. 4, only the staircase (sub-surface A_{13}) is equipped with insulating glass modules – the rest of the façade is equipped with double glass modules, such as the southwest façade.

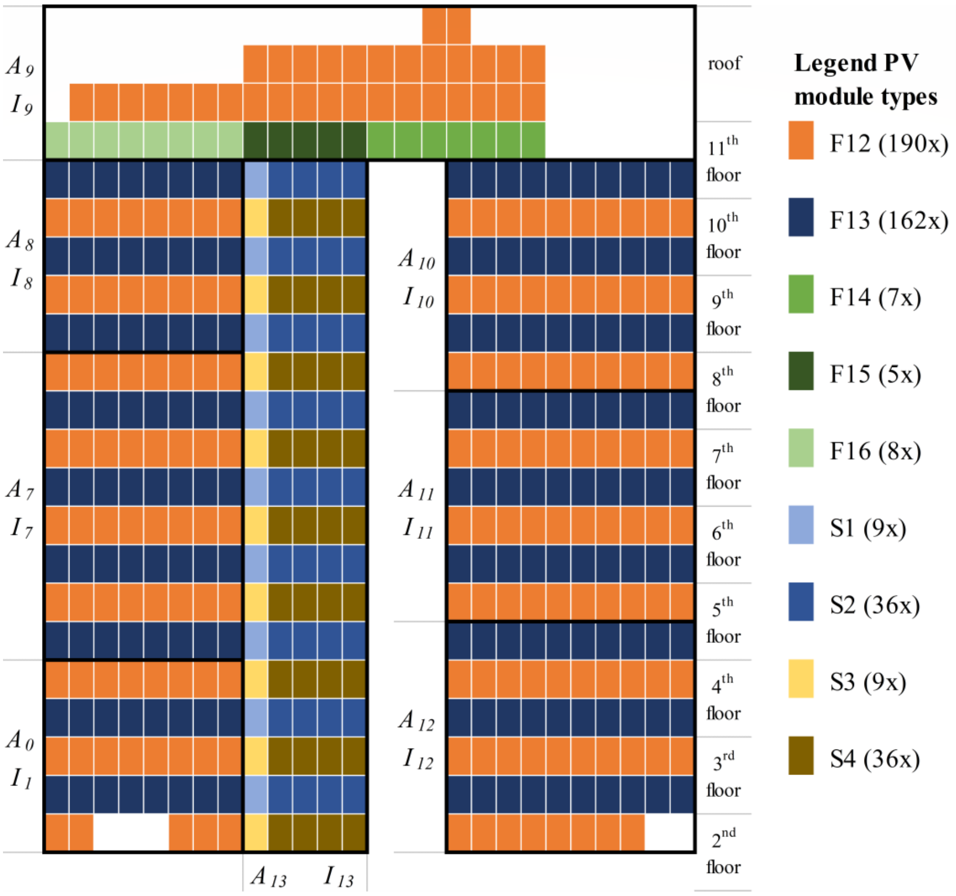

Fig. 4: Schematic representation of the PV system integrated into the southeast façade

Tab. 1 gives an overview of the installed PV modules. Their designation matches the module type designations in Fig. 2, Fig. 3 and Fig. 4. The table shows that all modules have monocrystalline wavers. The majority of the modules has a nominal power of approximately 300 W, a length of 2 m and a breadth of 1 m. Generally, the PV insulating glass installed in the southeast staircase façade is slightly smaller in size but disproportionally smaller in terms of nominal power. The reason for the disproportionally lower power is that the modules are semi-transparent, i.e., the gap between the PV modules silicone wavers is significantly larger than usual.

All of the installed modules are fairly common modules that were available on the market. Their only real special feature is that each module had to be equipped with a power optimiser. This additional component optimises the energy yield per module and prevents a single shaded PV module from reducing the output of all other modules that are connected in the string. The use of such a power optimiser is particularly useful for PV systems that are often partially shaded during the day. Since the (Plus-)Plus-Energy Office High-Rise Building is the only high-rise in the area, its PV systems are hardly shaded. The reason why power optimisers were installed is that they have a special safety feature that allows the DC voltage to be reduced to touch-safe values at the module level. This safety function was a requirement from the firefighters. It ensures that the PV modules do not pose any danger to them.

Tab. 1: Overview of the installed PV modules

Module	Type	Number	Part of	Length in mm	Breadth in mm	Power in W
F1	Double glass module (monocrystalline)	1	Southwest façade	1,580	1,021	225
F2		1		1,585	1,021	225
F3		9		2,000	1,021	300
F4		109		2,000	736	200
F5		208		2,000	1,051	300
F6		10		2,000	531	100
F7		9		1,845	1,021	275
F8		10		1,845	531	92
F9		10		1,660	736	150
F10		19		1,660	1,051	225
F11		1		1,660	531	75
F12		190	Southeast façade	1,845	1,056	275
F13		162		2,000	1,056	300
F14		7		1,080	1,056	150
F15		5		1,010	1,056	125
F16		8		1,585	1,056	225
S1	PV insulating glass (monocrystalline, semi-transparent)	9	Southeast staircase façade	2,046	846	185
S2		36		2,046	841	185
S3		9		1,901	846	165
S4		36		1,901	841	165
D1	Standard module (monocrystalline)	292	Roof	1,949	989	305
D2		29		1,629	989	255

Tab. 2: Overview of the sub-surfaces of the PV plant

Sub-surface	Inverter	Part of	Area (total aperture area) in m²	Power (total nominal power) in W
A_0	I_1	Southeast façade	74.7	10,575
A_1		Southwest façade	47.2	5,942
A_2	I_2		124.9	17,434
A_3	I_3		132.6	18,534
A_4	I_4		132.6	18,534
A_5	I_5		132.6	18,534
A_6	I_6		133.0	18,617
A_7	I_7	Southeast façade	129.9	18,400
A_8	I_8		81.9	11,600
A_9	I_9		91.0	12,550
A_{10}	I_{10}		121.8	17,250
A_{11}	I_{11}		121.8	17,250
A_{12}	I_{12}		117.9	16,700
A_{13}	I_{13}	Southeast staircase façade	149.6	15,750
A_{14}	I_{14}	Roof	108.4	17,155
A_{15}	I_{15}		100.2	15,860
A_{16}	I_{16}		100.2	15,860
A_{17}	I_{17}		98.3	15,555
A_{18}	I_{18}		102.2	16,165
A_{19}	I_{19}		100.2	15,860
Southwest façade sum			702.9	97,595
Southeast façade sum			739.0	104,325
Southeast staircase façade sum			149.6	15,750
Roof sum			609.6	96,455

Tab. 2 gives an overview of the sub-surfaces of the PV plant. It presents the total aperture area and the total nominal power of each surface. Further, the table shows how the sub-surfaces are connected to the plant's inverters. As it can be seen in the table, each sub-surface is generally connected to only one inverter – with one exception: Sub-surface A_0 of the southeast façade and A_1 of the southwest façade share inverter I_1. The designations of the surfaces and the inverters in Tab. 2 match the designations in Fig. 2, Fig. 3 and Fig. 4.

3. Method

In this section, we explain how the PV electricity generation of the inverters of the different sub-surfaces is measured by the building's energy monitoring, and how the measurements were prepared before comparing them with the electricity yield that the PV should have according to the simulations. Further, we describe the calculations that were made in order to investigate the building's self-consumption in dependence of battery size.

There are two energy monitoring systems: (i) the main building energy monitoring system that is heavily interconnected with the building operation system and (ii) the energy monitoring system of the manufacturer of the inverters and power optimisers. While (ii) has the advantage that it is accessible via a web interface, the data that can be extracted from this interface is limited. Basically, only data from the energy yield of the entire PV plant can be exported. To get a more detailed look on the performance of the PV plant, its inverters were connected to (i) and thus data from their internal electricity meters became accessible. Therefore, in the main building energy monitoring system there is data from 20 electricity meters related to the PV plant: The 19 electricity meters of the 19 inverters and the PV main meter in the low-voltage main distribution.

Besides these 20 electricity meters, the main building energy monitoring system also logs data from other energy meters (electricity and thermal energy for heating and cooling), operational data (sensor data, setpoints and control signals) and weather data (external air temperature, global radiation, wind speed, …).

As the monitoring data from 2018 has practically without gaps, it was chosen as basis for this work. Even though the monitoring system worked almost flawlessly, some of the inverters of the PV plant did not. There was an issue with inverter I_{14}, which lasted until 2nd May of 2018, and another issue with inverter I_3, which started on 15th September 2018. During the stated timespans, both inverters did not transform and supply any of the energy provided by the PV modules connected to them. To estimate the yield that those inverters would have had if there were no issues, the monitoring data from the inverters of the neighbouring sub-surfaces were used for extrapolations.

During the planning of the PV plant, simulations were conducted with PV*SOL Expert 6.0 (R8) to calculate the electricity yield that can be expected by the plant. As the provided report of the calculation results only shows the monthly yield of each of the four main surfaces (roof, southwest façade, southeast façade and southeast staircase façade), the comparison between the simulated yield and the measured yield had to be conducted on that level of detail.

As the (Plus-)Plus-Energy Office High-Rise Building was designed to be a net-zero energy building instead of a fully self-sufficient building, it is dependent on the connections to the Viennese energy grids (electricity grid and district heating). Electricity that is not provided by the local energy sources is drawn from the grid and a surplus of electricity is fed back into the grid. As the buildings of the university campus at the “Getreidemarkt” are connected, the surplus electricity is not really fed back, but practically always consumed by other university buildings. For easier readability of this work the phrase “electricity fed back into the grid” also refers to the electricity surplus that is consumed by the other buildings at the campus.

During the planning of the building there was the premise that only measures that are economically feasible (when considering life cycle costs over 50 years) shall be implemented. Designing the building as self-sufficient building appeared to be so unfeasible that it was never even considered an option. With the data from the building’s planning and the monitoring data from 2018 this option was now explored and the results are presented in this work.

It was assumed that the building was equipped with a battery storage. If there was a surplus from the PV plant this surplus electricity would be fed into the battery until it was full. Only then further surplus electricity would be fed into the electric grid. In the case that there is not enough electricity from the PV to cover the building’s consumption, the missing electricity would be drawn from the battery until it was empty. Only when the battery was empty further electricity would be obtained from the electric grid. For the sake of simplicity, the processes of feeding electricity in the battery and drawing electricity from the battery, were considered lossless.

The battery capacity of this fictional setup was varied and the respective load cover factor (LCF) and supply cover factor (SCF) were calculated as shown in eq. 1 and eq. 2 by using the following inputs:

- P_{SC} .... the electric power of the PV plant that is self-consumed by the building
- $P_{B,out}$ ..... the electric power drawn from the battery
- $P_{B,in}$ ...... the electric power fed into the battery
- P_C......... the total electric power consumed by the building
- P_{PV} .... the total electric power provided by the PV plant

$$LCF = \frac{\int P_{SC} + P_{B,out}\, dt}{\int P_C\, dt} \qquad \text{(eq. 1)}$$

$$SCF = \frac{\int P_{SC} + P_{B,in}\, dt}{\int P_{PV}\, dt} \qquad \text{(eq. 2)}$$

The equations were not solved analytically, but instead approximated by an hourly time discretisation. While the LCF expresses how much of the load can be covered by the local PV supply (incl. battery), the SCF expresses how much of the entire local PV supply can be consumed on site. An LCF of exactly one would indicate that the building is self-sufficient and a SCF of exactly one would indicate that all of the PV supply is consumed on site.

Considering that the building's heating demand is covered by heat from the Viennese municipal heating grid and partially by the building's server waste heat recovery, the fictional setup is not complete – the calculated LCF and SCF only represent the electricity supply and consumption. To setup the (Plus-)Plus-Energy Office High-Rise Building as true fully self-sufficient building, the heat would have to come from a local resource (e.g. a heat pump) and the electricity needed to draw heat from this resource would have to be considered when calculating the LCF and SCF.

4. Results

Based on the setup and specifications presented in the previous sections, we now show the results for the comparison simulated and measured performance of the PV plant of the (Plus-)Plus-Energy Office High-Rise Building for the data of 2018.

Fig. 4 illustrates the specific annual yield of electric energy of each of the sub-surfaces of the PV plant – calculated out of the energy monitoring data from 2018. The surfaces are coloured according to the value of the specific annual yield – ranging from blue (the lowest value) over grey up to orange (the highest value).

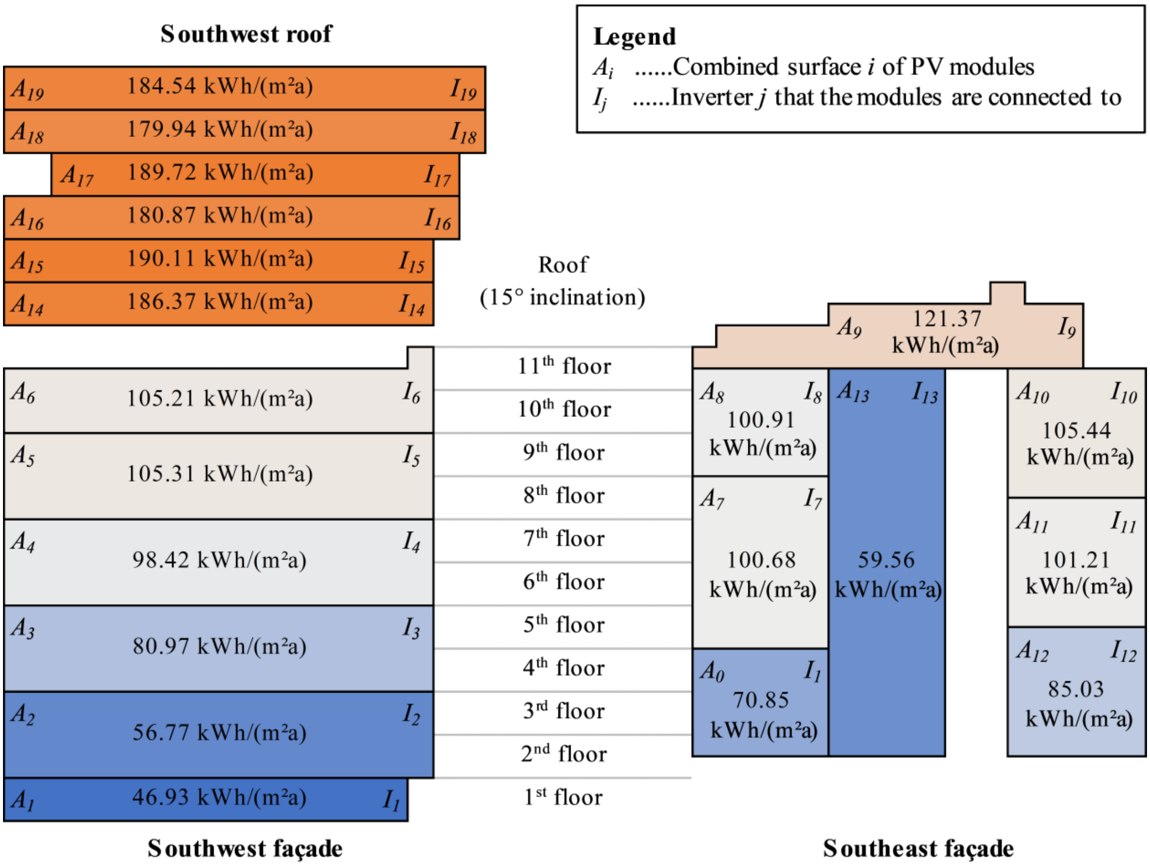

Fig. 4: Overview of the specific annual yield of electric energy of each sub-surface of the PV plant (the shown values are the extrapolation without inverter faults)

In Fig. 4 the values of inverter I_3 and I_{14} are the extrapolated values that the inverters were expected to have had if they were functioning properly without faults.

The distribution of the specific annual yield looks as expected: A sub-surface on the southwest oriented roof can provide much more electricity than each of the sub-surfaces of the façades. The higher up a façade sub-surface is, the higher its yield. Even though the building is the only high-rise in the vicinity, its lower façade sub-surfaces are still affected by the shading of the surrounding buildings. The results from the southwest façade indicate that only sub-surfaces above the $6^{th}/7^{th}$ floor appear to be unaffected by the shading of the surrounding buildings.

The sub-surface A_9 on the top of the southeast façade has a significantly higher yield than the sub-surfaces directly below it (A_8 and A_{10}). It appears that the reason is the partial shading by the protruding staircase (A_{13}).

Fig. 5 shows the absolute monthly yield of electric energy that each of the four main surfaces (roof, southwest façade, southeast façade and southeast staircase façade) had during 2018 and contrasts it with the simulation results from the planning. As there was no correction for different weather conditions in the simulation and the monitoring, the graph can only indicate general tendencies.

The displayed values from 2018 are the real measurements – the total monthly yields that were expected if there were no inverter faults are displayed separately as short black lines. As inverter I_{14} did not work properly until 2nd May and as it is one of the inverters of the PV system on the roof, the missing electricity yield is relatively significant. This becomes especially obvious when analysing the yield of April – the faulty inverter reduces the yield by 8%. Even though inverter I_3 (which failed after 15th September) is only an inverter of a lower façade sub-surface, the impact of its failure is significant as well – its failure reduces the yield of October by 5%.

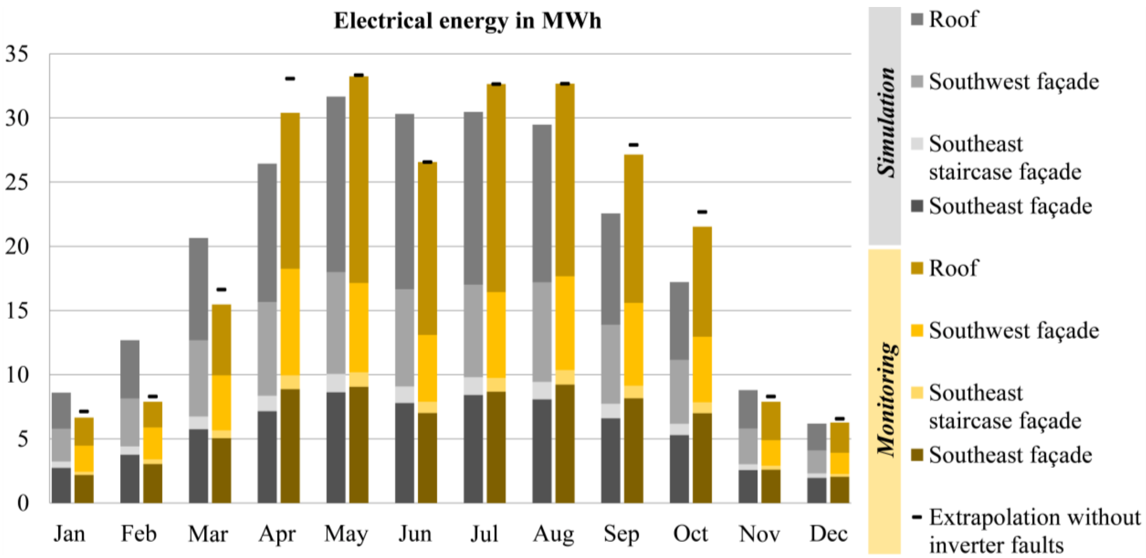

Fig. 5: Comparison of the PV plant's design performance and the performance measured in the year 2018 (Basis: AC-side of the inverters)

The general magnitude of the simulated and the measured yield in Fig. 5 is identical – the simulation seems to be a valid way to predict the real performance of the PV plant. When analysing the proportions of the yield of each of the main surfaces, there are slight indications that: (i) the PV system on the roof performs better than in the simulation, (ii) the system of the southeast façade (without staircase) performs as expected and (iii) the systems of the southeast staircase façade and the southwest façade perform worse than in the simulation.

For a more detailed comparison, the simulation would have to be repeated with the weather data measured during 2018.

As the main aspect of the (Plus-)Plus-Energy Office High-Rise Building is not only its PV plant but also the goal of producing more electricity on site than the building consumes during the year, the following analyses focus on the interplay between production and consumption. By calculating the difference between the PV electricity production and the building's consumption for every hour during the year and ordering the values in a descending order, the load duration curve – see Fig. 6 – can be calculated. It is a characteristic curve that illustrates the levels of electric power that the building feeds into the electric grid (positive values) or draws from the electric grid (negative values) during the course of a year.

Fig. 6 shows the load duration curve for four cases, where the PV production is varied between the measured values of 2018 and estimated values if there would not have been inverter faults, and where the building consumption is varied between the measured values of 2018 and the design consumption. It can be seen that the maximum electricity surplus that can be expected to occur in the building is approximately 150 kW. In the case of design consumption and the extrapolated PV production, this value increases to 160 kW. With the ability to shift or store electrical power up to values of 100 kW, almost all of the building's surplus energy could be utilised.

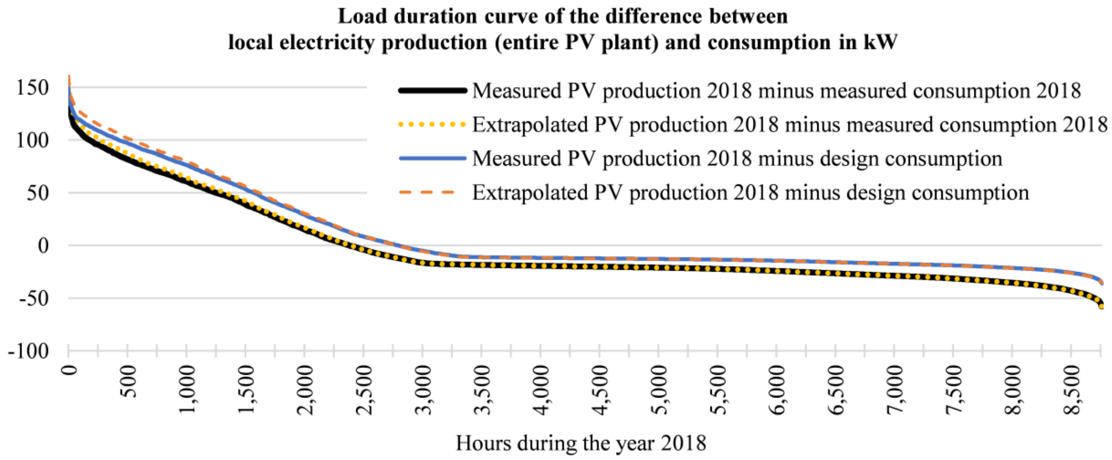

Fig. 6: Load duration curves calculated for four different cases (Basis: PV main meter; entire PV plant)

Further, it can be seen that in the cases with the measured consumption of 2018 during almost half of the year the electrical power drawn from the grid is between a band of 15 kW and 30 kW. For the case of the design consumption the power drawn from the grid lies between a band of 10 kW and 20 kW for a duration of slightly more than half a year.

As the entire PV plant also covers some building parts outside of the system boundary zone of the (Plus-)Plus-Energy Office High-Rise Building, Fig. 7 shows the same graph as in Fig. 6 for the case where only the PV inside the boundary zone is considered in the calculations. The right side of both graphs is identical – the course of the curve on the left side between hours 0 and 3,000 is flatter. Resulting in a maximum surplus of approximately 118 kW (extrapolated PV production and measured consumption) or 126 kW (extrapolated PV production and design consumption). With the ability to shift or store electrical power up to values of 80 kW, almost all of the building's surplus energy could be utilised.

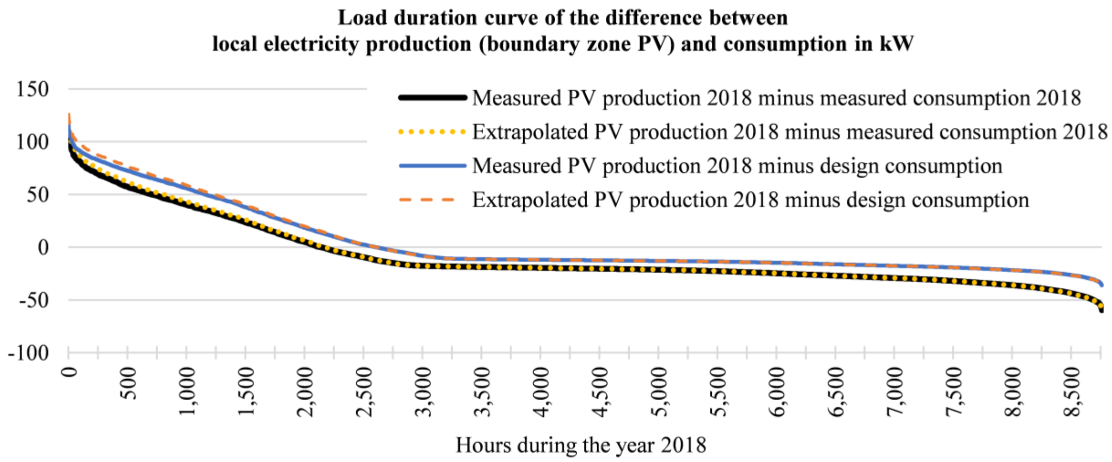

Fig. 7: Load duration curves calculated for four different cases (Basis: PV main meter; only the part of the PV plant that is assigned to the plus-energy boundary zone)

A more detailed view of the electricity surplus that can be expected by the (Plus-)Plus-Energy Office High-Rise Building's PV plant is illustrated in Fig. 8. This figure shows two of the days of 2018 which had the highest PV electricity surplus – one day of the work-week and one day of the weekend. If the building would have the design consumption and there would not have been inverter faults during 2018, the surplus of these days is estimated as 0.76 MWh (entire PV plant 1.04 MWh) and 0.87 MWh (entire PV plant 1.12 MWh). A surplus of 0.87 MWh is enough to cover the electricity consumption of more than one day (average daily consumption as measured during 2018: 0.743 MWh) respectively almost two days (average daily consumption as designed: 0.464 MWh).

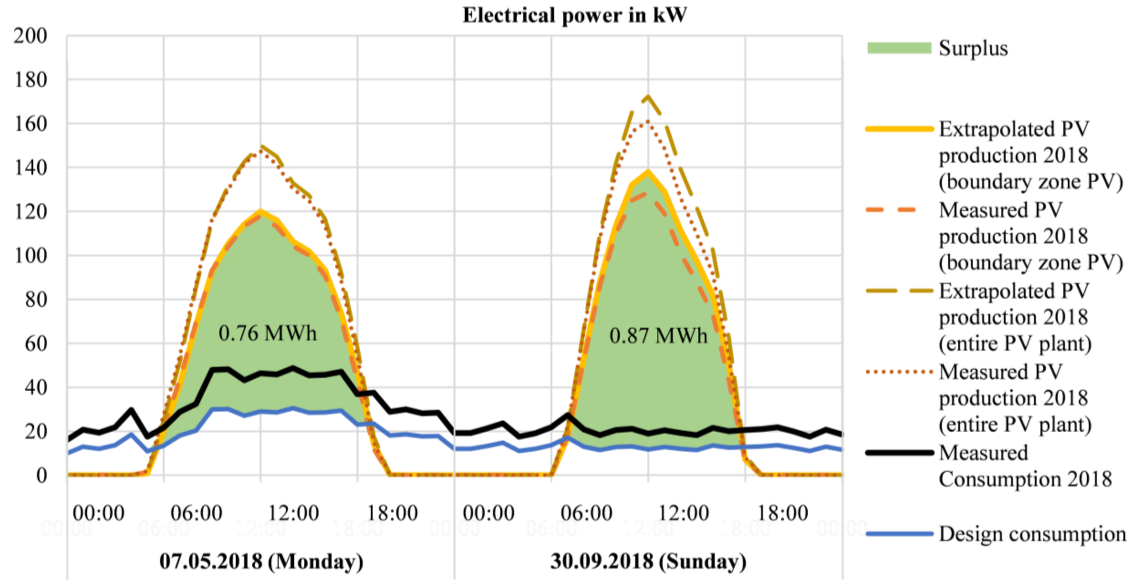

Fig. 8: Electricity supply and consumption load profiles of the two days of 2018 which had the highest PV surplus (Basis: PV main meter)

For the case that the building would achieve the design consumption, 37.8% of the PV production (boundary zone PV; extrapolated PV production) would be self-consumed and 44.3% of the load would be covered by it. According to the unaltered monitoring (boundary zone PV; measured PV production) the self-consumption was 54.6% and 40.0% of the load was covered during 2018. All these values can also be found in Fig. 9 at a battery capacity of 0 kWh.

Fig. 9 illustrates the results of a fictional setup where the building is assumed to be equipped with a battery storage. This is basically the first step of a simplified feasibility study. In this setup the battery capacity was varied and the corresponding load cover factors (LCF) and supply cover factors (SCF) were calculated as described in Section 3. The maximum value for the battery capacity was chosen so that the LCF reached a value of exactly one for the case of the design consumption. This capacity is the absolute minimal capacity that the battery of the building would have to have in order that its electricity system is fully self-sustaining.

Given the situation that the building would achieve its design consumption and the PV production would be like the one of 2018 without inverter faults (extrapolated PV production), this minimal capacity would be 32 MWh. If the PV production would be like the one of 2018 with inverter faults (measured PV production), the minimal capacity would increase to 34 MWh. Considering that in reality there are losses when loading and unloading the battery, and that a true self-sustaining system should have some reserves to compensate for further failures, unexpected weather conditions and the degradation of the PV modules, the real capacity would have to be much higher. As even the lowest minimal capacity of 32 MWh equals the energy of 69 days with average daily consumption (0.464 MWh as designed), the goal of setting up the building as a self-sustaining building appears unreasonable. Especially when considering the fact that the consumption measured during 2018 exceeded the design consumption and the fact that the fictional setup only addressed the electricity demand and not the heating demand, it becomes obvious that fully self-sustaining office high-rise buildings are a technological and economical challenge.

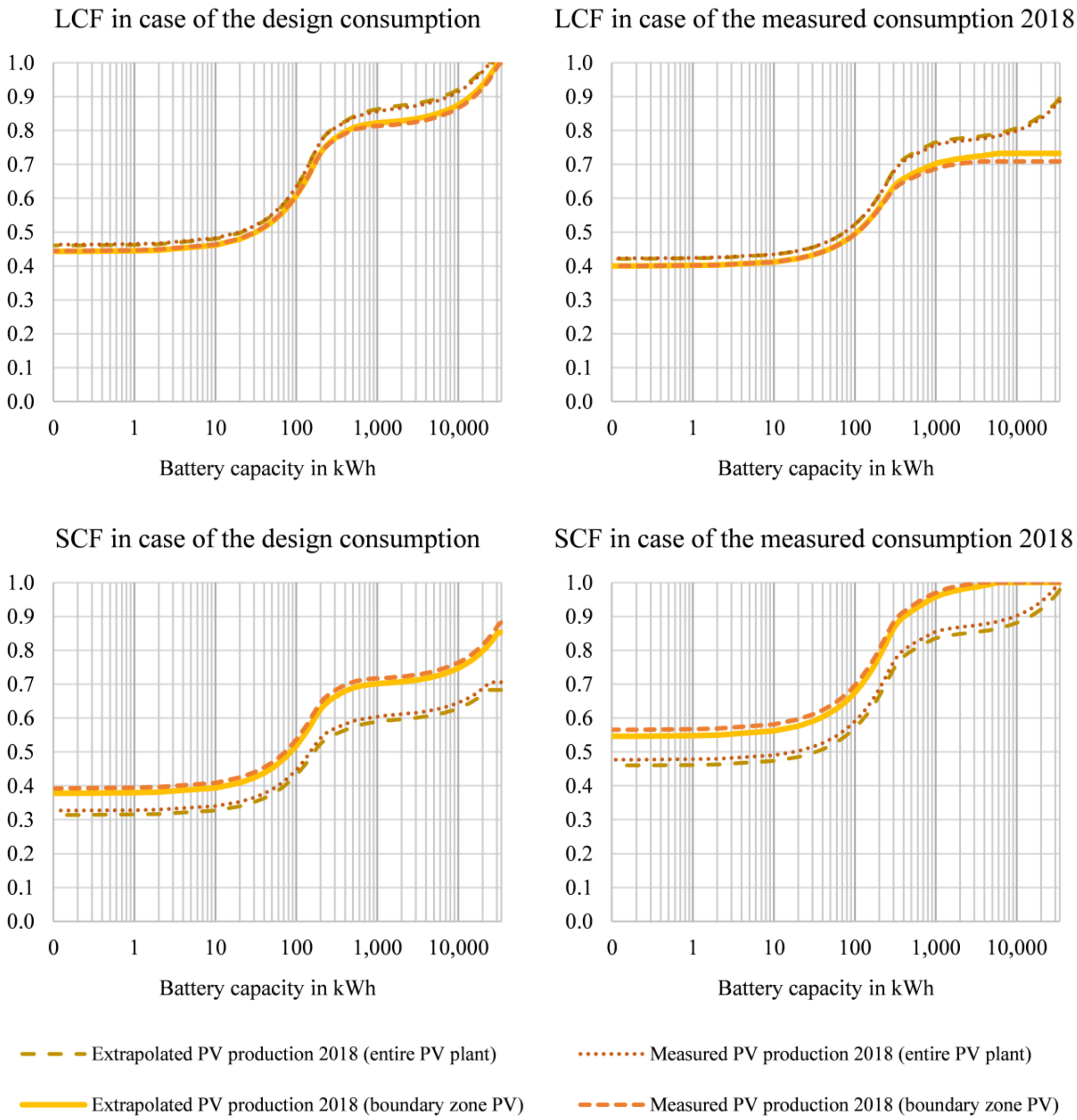

Fig. 9: Overview of the load cover factors (LCF) and supply cover factors (SCF) that could be theoretically achieved if the (Plus)-Plus-Energy Office High-Rise Building would be equipped with batteries of different sizes (losses are neglected)

5. Conclusion

Even though there were some inverter failures, the monitoring data of the PV plant of TU Wien's (Plus-)Plus-Energy Office High-Rise Building seems to fit the simulation results. The net-zero energy concept of the building works well within the setting of the whole university campus – there are enough other buildings that consume the electrical surplus of the PV plant. If the high-rise building would not be connected to the other university buildings or if they would have comparable energy concepts, there should be possibilities to shift more than 0.87 MWh (entire PV plant 1.12 MWh) electrical energy with an electrical power of 80 kW (entire PV plant 100 kW) from one day to another.

Depending on the real consumption of the high-rise building, the self-consumption of a comparable building without capabilities to shift or store electricity, can be expected to be between 37.8% and 54.6%. Further, it can be expected that between 44.3% and 40.0% of the building's electricity load will be covered by the PV supply. Even if a comparable building would achieve the design performance of the (Plus-)Plus-Energy Office High-Rise Building, it is not reasonable to set this building up as self-sustaining building – it would need battery capacities large enough to store more than three months' worth of electricity consumption.

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