MASTER'S THESIS

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Optimizing integration of renewable energy: advancements in control and management strategies

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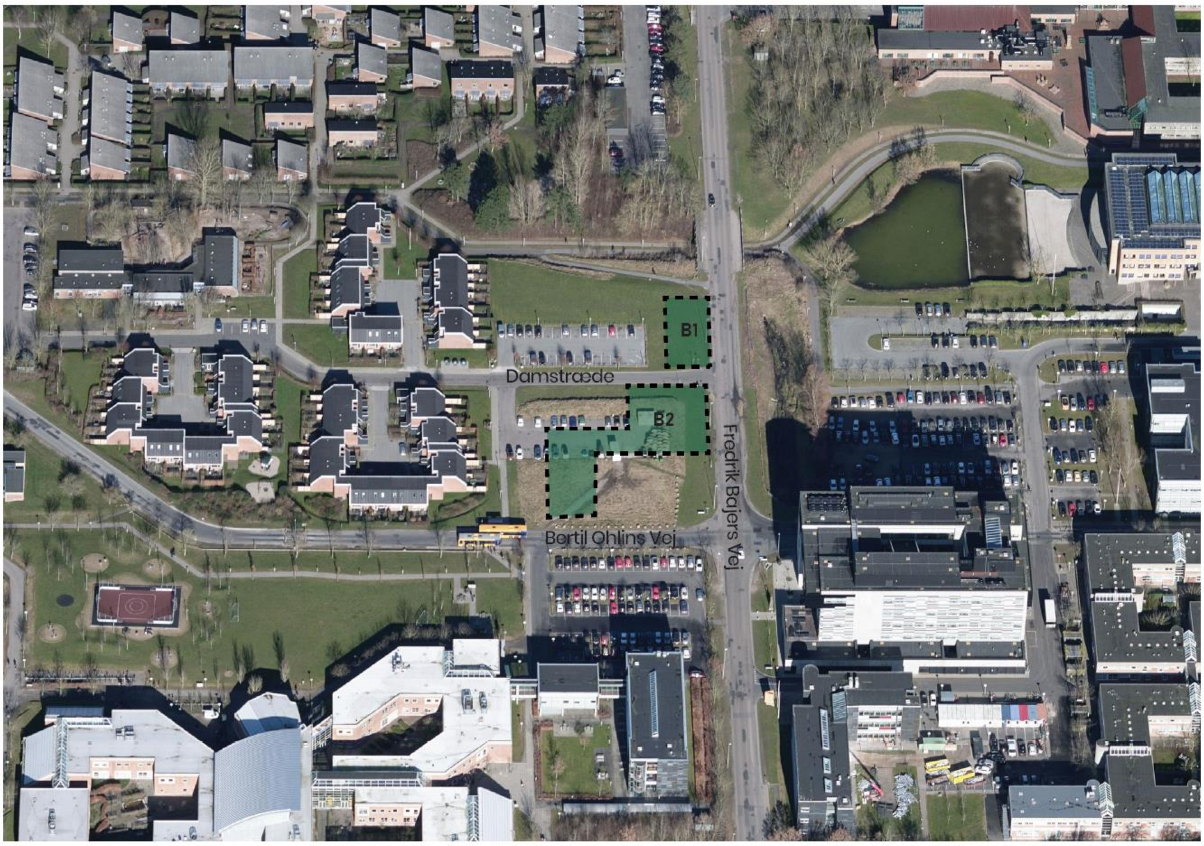
GREENGUB HOUSE



Det todelte byggefelt B1 og B2 ligger i Universitetsområdet i Aalborg ved krydset Bertil Ohlins Vej/Fredrik Bajers Vej.

Abstract:

The Green Hub House initiative is dedicated to meeting residents' electricity needs by incorporating solar cells. To ensure year-round efficiency, our team utilized PVsys 7.4 software to conduct a thorough simulation of the optimal installation angles for the solar cells based on the project's geographic location. By comparing various installation scenarios and examining outcomes based on critical factors, we integrated production results with consumption data from a major energy company client, NRGI, to create a sound strategy for adopting solar cells.

Next, our team focused on defining and calculating the necessary battery storage system, as well as determining the required connections and quantities. Using MATLAB, we simulated the connection of the local solar cell network to the regional power grid. In the following phase, we analyzed the impact of solar cell utilization on carbon dioxide reduction across different scenarios. Finally, through meticulous cost analysis and payback period calculations, we assessed the economic feasibility of utilizing solar cells. This comprehensive approach provides valuable insights into the sustainable implementation of solar technology for residential energy systems.

Acknowledgment:

I would like to express my sincere gratitude to all those who contributed to the successful completion of my thesis. I am especially grateful to Professor Per Kvols Heiselberg for his invaluable advice and guidance throughout my academic journey. His mentorship has been like a rich classroom, offering me continuous opportunities to learn, grow, and enhance my knowledge. I appreciate his patience and dedication to my academic development.

I also want to acknowledge my wife, Yosra Masoudi, for her unwavering support and presence throughout my life over the past 15 years. During the last summer and fall, her kindness and unwavering support took on an added dimension as she assumed additional responsibilities, creating a conducive environment for the research and successful completion of this project. Her contribution has been instrumental in this endeavor, and I am profoundly grateful for her companionship.

To everyone who played a role, big or small, in this academic endeavor, I extend my heartfelt thanks. Your support has been instrumental, and I am truly appreciative of the collaborative effort that has resulted in the culmination of this thesis.

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Chapter 1 Introduction:

1.1. Problem background

The Green Hub House Project is part of a global movement towards diversifying energy sources and prioritizing sustainability, with researchers exploring ways to shift from fossil fuels to renewable resources such as solar and wind power. This aligns with the UN's 2030 sustainable development goals. Denmark has been a leader in this effort, implementing successful micro-grids and smart grids that rely on renewable resources. However, the development of smart homes based on microgrids faces economic challenges, particularly in justifying investments in major construction projects. To address this issue, governments like Denmark have implemented strategic subsidies and tax exemptions to encourage large construction companies to invest in smart and green microgrids, which aim to produce both electricity and heat while promoting environmental sustainability. To ensure success, governments and organizations have updated regulations and standards in response to changes in technology and energy landscapes. The significance of creating smart microgrids has been reinforced by recent political and economic circumstances, including the COVID-19 pandemic and the Russian military assault on Ukraine. These occurrences have compelled individuals and governments to recognize the importance of durable and intelligent energy systems in the face of worldwide challenges. Each microgrid and smart grid serves as a testament to the progress made in making energy systems more comprehensive and environmentally friendly, reflecting the continuous evolution and refinement of ideas in green architecture and sustainable development.

1.2. Literature Review:

Introduction:

The integration of renewable energy systems in residential buildings is becoming increasingly important in the push for sustainable and efficient living. Photovoltaic (PV) systems are a key technology for producing clean and renewable electricity. This literature review examines various aspects of PV systems in the context of green hub houses, focusing on their impact on energy efficiency, reducing electricity and energy production costs, return on investment, and their role in reducing carbon dioxide production.

Energy efficiency and PV systems:

Several studies have shown the positive impact of PV systems on the energy efficiency of residential buildings sanaz tabasi (tabasi, 2019) analyzed PV integration angles and their effect on energy production efficiency, considering variations in geographic location and seasonal changes to optimize the angle of PV panels for maximum energy efficiency. Similarly, m. torresi (m.torresi, 2014) investigated the integration of smart energy management systems with PV technology and highlighted the potential to increase energy efficiency through smart demand response mechanisms.

Economic considerations:

The economic viability of PV systems in residential environments is an important aspect that affects the adoption rate. Research by s. singh (s.singh, 2019)) addresses the economic aspects of PV integration, considering factors such as installation costs, maintenance, and return on investment. Their findings suggest that advances in PV technology and reduced installation costs will contribute to the economic feasibility of residential PV systems. In addition, (Pupo-Roncallo, 2019)analyze the economic benefits of integrating energy storage solutions, such as batteries, with PV systems and provide insights into the long-term economic benefits of hybrid systems.

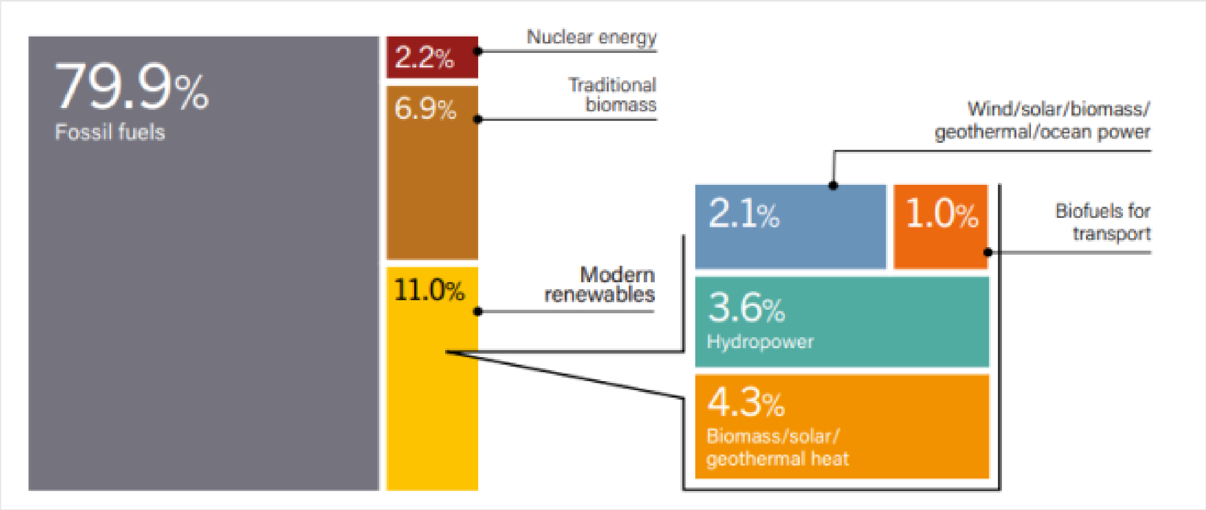
Battery technology and PV integration:

The choice of energy storage solutions, especially batteries, significantly affects the overall performance and reliability of PV systems. (hanif, 2019)present a comparative study of different battery technologies and evaluate their suitability for residential PV applications. This research shows the importance of selecting the right battery systems to handle the intermittent of solar energy generation and ensure a reliable power supply. Additionally, the study of (Rydh, 2003)explores the potential synergies between PV systems and emerging energy storage technologies and highlights battery technology advances that increase the overall sustainability of green hub homes.

Conclusion:

In conclusion, the reviewed literature emphasizes the multifaceted role of PV systems in green hub houses. From optimizing energy efficiency through intelligent management systems to considering economic aspects and integrating advanced battery technologies, researchers are actively exploring ways to increase the sustainability and effectiveness of residential PV applications. This comprehensive review provides valuable insights for policymakers, engineers, and homeowners interested in harnessing the full potential of PV systems in the context of green hub home. ((https://jarphys.wordpress.com/2019/07/02/renewable-energies-status-report/, 2019)

Figure 0.1 renewable energy



1.3. Problem Formulation:

How the integration of solar cells can help increase environmental protection because of reducing the production of carbon dioxide and increasing the stability of the national grid by reducing consumption and effective management of consumption through local production.

Problem: Residential houses consume substantial energy for heating, cooling, and electricity, leading to high utility bills and carbon emissions.

1.4. Methodology:

Our primary goal was to assess the effects of solar cells on grid stability (To prove the effect of integrating solar cells on the stability of the power grid, the effect of these systems in regulating the voltage and especially the frequency and reducing losses in the distribution network (Razavi, 2020). The section that has examined the performance of batteries in peak load can mention that by supplying a part of the grid consumption, the consumption load from the national grid increases because of the balance in power and frequency. Some of these calculations are given in the appendix section. Page 125to 131) and carbon dioxide emissions. To achieve this, we meticulously analyzed the geographical conditions of the project site and gathered relevant data from meteorological systems. With the help of PVsyst7.4 software, we calculated the production capacity of a solar cell at that specific location and experimented with different installation angles to optimize sunlight exposure. Next, we merged our consumption range data with the simulations we had created to devise a comprehensive installation plan. This involved identifying the system's purpose, storage requirements, and desired coverage percentage. Finally, we examined the impact of various factors on consumption and explored the use of capacitors to boost the system's capabilities. Our ultimate objective was to improve the system's performance and facilitate greater consumption via the local network.

1.5. Research objective and relevance:

The aim of this thesis is to explore the role of solar cells in projects, with a focus on achieving system stability by covering a portion of the building's electricity consumption while simultaneously reducing costs and improving consumption efficiency. Additionally, the study will examine the dynamic variables within the consumption system and explore the feasibility of installing a capacitor bank unit in the project. Integration of solar systems not only lowers costs but also reduces carbon dioxide production. The research will consider the policies of Aalborg Kommune as a local policy maker and how they align with the macro policies of the Danish central government, which aim to reduce dependence on fossil fuels.

1.6. Scope of thesis Limitation/Delimitation:

1.There are some limitations that need to be considered when conducting this research. Firstly, it's worth noting that at the time of writing this thesis, the project had not yet reached its final stage in terms of plans and formal agreements. As a result, if there were any physical improvements during the writing process, a clearer and more comprehensive vision for defining the scenarios could have been achieved, and the layout of the solar cells might have been more aligned with local reality.

2.Secondly, when estimating all expenses associated with procuring and installing the solar cell system, it's important to acknowledge that the absence of actual field plans for the building may lead to variations in the relevant calculations.

3.Thirdly, during the interview with the contractor company, it became clear that the definition of a zero-energy building is more towards the preparation of materials than the overall design of the energy supply plan. Hence, the conflict in views on how to view and define an energy hub acts as a limitation.

Finally, in our efforts to forecast consumption patterns, we have employed dynamic variables. Despite exploring multiple scenarios, it's important to recognize that achieving 100% certainty in predicting consumption patterns is challenging. Factors such as unit sizes and the diverse cultural norms and habits of residents in these buildings significantly influence energy management and control, presenting inherent complexities.

1.7. The Structure of The Thesis:

1. The initial chapter presents an overview of the subject matter, encompassing the issue at hand, an evaluation of previous research, the aims of the study, the approach utilized, and any limitations of the thesis.

2. In the subsequent chapter, we scrutinize the relevant case study and the proposed strategies.

3. The third chapter centers on production and employs system simulations to analyze production, consumption, battery systems, and economic considerations.

4. Chapter four explores demand, utilizing data obtained from NRGI to investigate consumption and integrate it with the discoveries from Chapter three.

5. The fifth chapter is dedicated to the battery, including the selection of the appropriate model, an exploration of how the battery is integrated into the grid, and a study of its behavior in various scenarios. Additionally, we establish our approach and the role of the battery.

6. In chapter six, we delve into the economics of the project, calculating and estimating the price of the proposed scenario and the anticipated return on investment based on key factors.

7. The seventh chapter addresses CO2 emissions and the potential for our scenarios to reduce carbon production.

8. Chapter eight takes a closer look at smart microgrids and the role of smart measuring in smart homes, as well as the impact of green hub energy.

9. Lastly, the ninth chapter and tenth chapters provide a conclusion and discussion of the findings presented throughout the thesis, synthesizing the data, and highlighting their implications.

1.8. What is the Green Hub House project:

This project is dedicated to identifying the main challenges associated with categorizing low CO2 emissions, energy efficiency, and indoor environmental quality. We are also exploring potential opportunities and obstacles to tackling these challenges to revolutionize sustainable construction practices. One specific objective that has caught my attention is the development of new control and management strategies that can automatically utilize integrated energy systems within buildings. Throughout the Green Hub project, we have had to remain flexible in our proposals and scenarios due to incomplete information and pending decisions from contracting companies. As a result, I have taken on the task of designing and presenting proposals for various building types and sizes. It is worth noting that we aim to create a zero-carbon building design, which is essential for validating our scenarios.

The introduction, preface, problem statement, and methodology serve as the foundation for the scenarios that are designed using SYS software. Before designing, I carefully consider factors such as apartment area, household energy consumption, carbon dioxide emissions, and payback period.

Chapter 2 Theoretical Background:

2.1. Building consumption:

Following economic progress, industrial development, and global economic competition, the extensive exploitation of natural resources to meet growing consumer demand has brought to light the adverse environmental consequences associated with this path of economic development. Notably, the significant impact on the environment stems from the rise in urbanization and the expansion of urban settlements, positioning cities as primary contributors to environmental pollution.

Cities, acting as hubs of consumerism, exhibit an inherent tendency towards the excessive utilization of natural resources and energy. The repercussions of consumerism manifest in the generation of vast amounts of waste materials, surpassing the capacities of environmental regeneration and recycling processes. In contemporary discourse, there is widespread acknowledgment that sustainability holds paramount importance for both individuals and societies.

Historically, manufacturing methods and techniques have played a substantial role in carbon emissions. Recognizing these shortcomings, concepts such as green architecture and zero-emission structures have emerged as viable alternatives to conventional approaches. The objective of these approaches is to establish spaces in harmony with nature, ensuring heightened sustainability while significantly diminishing dependence on resources like fossil fuels.

Recent years have witnessed an increased awareness of environmental issues, encompassing climate change, pollution, and the depletion of natural resources. This heightened awareness has spurred the construction industry to embrace new methods and strategies aimed at minimizing its impact on carbon dioxide production, ultimately striving for zero emissions. The construction of buildings using recycled materials or adopting innovative techniques to reduce reliance on traditional industrial materials represents a noteworthy paradigm shift. This approach not only mitigates environmental impact but also prioritizes visual comfort, psychological security, and thermal comfort, collectively referred to in modern terms as a "green" approach.

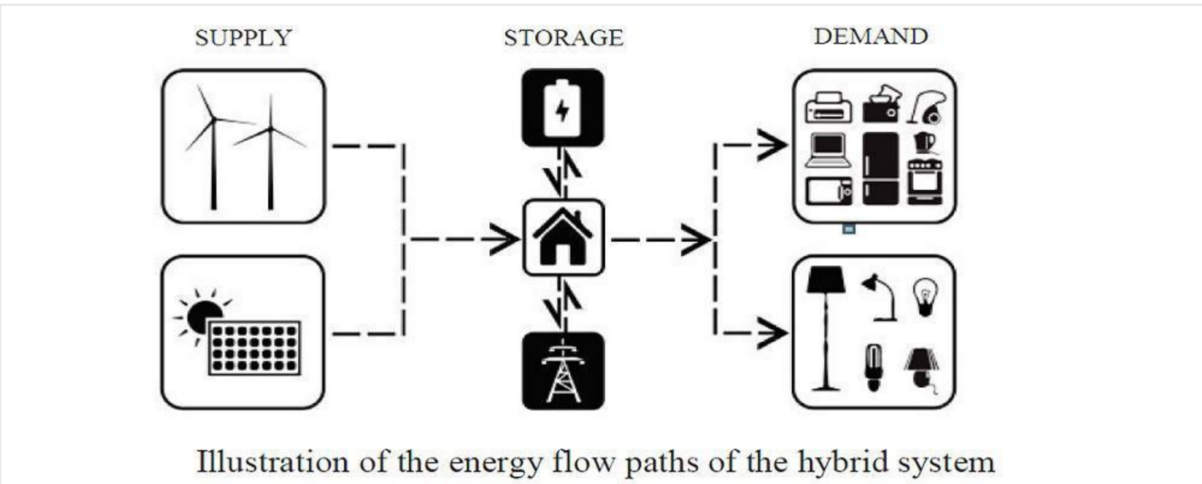


Figure 0.1 illustration of energy flow paths of the hybrid system. (Jones, Oct 20149)

More than one-third of energy in the world is consumed in buildings, most of this energy is used for heating, cooling, and lighting the building. More than 80% of the energy used in buildings comes from fossil fuels, which are limited.

The growing trend of energy consumption makes the world face a big challenge in energy supply. Buildings are one of the main sources of energy consumption, that's why they need constructions in which energy consumption is optimal. Passive houses are designed to optimize energy consumption. Passive houses are houses that are designed according to the climatic conditions of the region and using solar energy.

Definition of passive houses:

Passive houses are said to have the following three features:

1. Efficient and optimal energy consumption

2. Environmentally friendly

3. Cost-effectiveness

In these houses, the amount of energy consumption has been reduced by 90% compared to normal houses, and it requires only 10% of the energy of normal houses. Passive houses consume 75% less energy than newly built houses. (https://passipedia.org/basics/what_is_a_passive_house)

2.2 Energy sources:

Denmark faces significant challenges due to limited natural resources. However, the nation has implemented strategic measures that have propelled it to become a global leader in terms of energy security. Despite this achievement, Denmark still imports around 17% of its electricity consumption. (https://ens.dk/sites/ens.dk/files/EnergiKlimapolitik/final_denmarks_global_climate_impact_-_global_report_2023.pdf, 2023)

2.3. Energy Sources in Denmark:

Denmark's energy supply sources can be broadly categorized into two groups: domestic and imported.

Driven by a commitment to zero carbon policies and a pioneering approach to green energy, Denmark has prioritized expanding renewable and green resources. Notably, fossil fuels and non-renewable resources only contribute to 28.6% of Denmark's net production, whereas an impressive 71.4% comes from renewable sources.

In February 2011, the Danish government introduced the "Energy Strategy 2050," outlining a goal to eliminate reliance on fossil fuels by 2050. This goal was reaffirmed by subsequent administrations in 2015. Denmark originally aimed to have 50% of its electricity generated from wind by 2020 and 84% by 2035; however, the plan shifted to achieving 100% renewable electricity production by 2030. Denmark's energy security ranks among the best in the EU, rivaling countries like Sweden and Finland, as its electricity grid connects with other European nations through transmission lines. (https://www.sgi-network.org/docs/2020/thematic/SGI2020_Environment.pdf, 2020)

Although Denmark produces more electricity than it consumes, it imports approximately 17% of its electricity needs. Most of this imported electricity is derived from hydroelectric and nuclear sources, both considered low-carbon energy sources.

Oil And Gas Situation:

Denmark possesses reserves of oil and natural gas in the North Sea. In 2008, it held the 32nd rank among crude oil exporters globally. However, Denmark's shift towards green and renewable energy has led to expectations that it will no longer require oil as an energy source by 2050. Importantly, Denmark imports about 12% of its energy, encompassing various forms of energy beyond just electricity.

Since 1972, Denmark has engaged in oil and gas production from its North Sea reserves. This industry remains a notable contributor to the government's revenue. While Denmark became an oil and gas exporter in 1997 (https://ens.dk/sites/ens.dk/files/OlieGas/oil_and_gas_in_denmark_2010.pdf, 2010), its global production and exports remain relatively modest. Relevant data is as follows:

Table 1. global production and export for Denmark

(https://www.modstroem.dk/nyheder/energikilder-i-danmark., energy source in denmark)

Oil storage capacity	5,510,000,000	barrels
Daily oil production	145,674	barrels
Daily oil consumption	158,194	barrels
Daily deficit	12,520	barrels
Daily oil import	77,224	barrels
Daily oil export	78,070	barrels
Net oil exports	846	barrels

As of 2016, Denmark's fixed reserves are equivalent to 9.5% of its annual consumption. Despite these reserves, Denmark's government decided to cease oil exploration in the North Sea, signaling a commitment to moving away from oil and gas production starting in 2050.

In 2019 the oil and gas industry accounted for 29% of gas consumption. The residential, service, and agricultural sectors followed, accounting for 29%, and the industry contributed 25%. (https://ens.dk/sites/ens.dk/files/Analyser/deco19, 2019)

Gas Reserves and Future Initiatives:

Despite being self-sufficient in oil and gas within the European Union, Denmark's domestic production doesn't fully meet consumption needs. The country relies on international oil companies for its production and consumption of oil and gas. This reliance prompted Denmark to augment its gas reserves, particularly after conflicts affected gas supplies following the Ukraine crisis.

Denmark expanded its gas reserves to ensure winter demand was met. In October of the present year, Danish energy organizations announced that gas reserves had reached over 85%, ahead of projections. This readiness positions Denmark to handle increased demand during the winter season. These reserves are expected to last for three months, supplemented by biogas production and gas imports from Europe.

Despite Denmark's gas resources, its zero-carbon policy has impeded the development of domestic oil and gas resources. Consequently, Denmark imports gas, predominantly from Russia through Germany. To enhance energy security, Denmark's largest energy company, rsted, partnered with the Norwegian firm Equinor, securing a gas supply agreement through the Baltic Pipe. This agreement spans from January 2023 to April 2024, with the supplied gas amounting to roughly 8 terawatt-hours, about a quarter of Denmark's total gas consumption.

The completion of the Baltic Pipe gas pipeline allows Denmark to purchase gas from Norwegian fields. This deal bolsters Denmark's gas supply security, particularly in times of European energy market instability.

Orsted S/A, previously known as Energy DONG, stands as Denmark's largest multinational energy company. By January 2022, it had become the world's leading offshore wind energy developer based on the number of offshore wind farms. Presently, 90% of its energy comes from renewable sources, and its goal is to achieve net zero generation by 2025 and zero carbon emissions by 2040. Orsted has been recognized as the world's most sustainable energy company in the Global Knights Corporate 100 list. (https://www.mckinsey.com/capabilities/sustainability/our-insights/orsteds-renewable-energy-transformation, 2019)

Equinor, previously ASA Equinor and StatoilHydro, is a state-owned Norwegian energy company active in oil and gas across 36 countries. It has also invested in renewable energy.

Coal Transition:

Wind energy is a significant contributor to Denmark's electricity generation, with coal only making up a small fraction of the mix. In fact, the country has set a goal to phase out coal completely by 2025. As of 2019, coal contributed less than 11% to electricity production, and this number is continuing to decrease.

Denmark began its ban on new coal-fired power plants back in 1996-1997, with the intention of transitioning existing facilities to alternative fuel sources and achieving complete coal-free electricity generation by 2030.

During the energy crisis that resulted from disruptions in the Russian energy supply, Denmark's authorities instructed rsted to continue operating three power plants that utilized oil and coal as fuel sources, in order to bolster electricity supply security. Additionally, they ordered the reactivation of previously halted oil and coal power plants, including Unit 3 at the Esbjerg Power Plant and Unit 4 at the Studstrup Power Plant (both coal-powered), as well as Unit 21 at the Kyndby Peak Load Plant, which uses oil. Although the Esbjerg plant was originally scheduled for decommissioning in March of 2023, various technical challenges and staffing shortages have arisen. Rsted is working to overcome these challenges and ensure that these units are operational as soon as possible.

Rsted has been directed to maintain these three units until June 30, 2024, which aligns with its broader objective of achieving carbon neutrality by 2025. (https://ens.dk/sites/ens.dk/files/EnergiKlimapolitik/final_denmarks_global_climate_impact_-_global_report_2023.pdf, 2023)

2.4. Renewable Energy Transformation:

Denmark's geographical limitations have prevented it from having significant hydropower resources, and government decisions have led to the non-utilization of nuclear power. Despite these challenges, wind energy has emerged as a critical player in Denmark's electricity generation, accounting for almost half of the country's electricity production. Denmark holds the impressive title of producing the most wind power per capita among OECD countries, with the Flak Kreigers wind farm being the largest in Scandinavia. Furthermore, Denmark has achieved a remarkable feat in green energy production in the first half of 2022.

2.5. Energy hub:

conversion and storage of different energies in a composite unit and proper communication between green hub Energy refers to the production and consumption of renewable and clean energy sources like wind, solar, water, biogas, and other alternatives. This concept prioritizes environmental preservation, reducing greenhouse gas emissions, and decreasing reliance on non-renewable energy sources such as fossil fuels.

Green Hub Energy opposes the use of polluting and unsustainable energies such as oil, natural gas, and coal. Instead, it aims to provide energy with minimal impact on the environment while preserving natural resources.

The goal of Green Hub Energy is to maintain a balance between energy production and environmental protection. This means that energy produced from renewable sources like wind and sun is provided continuously without any adverse effects on the environment. Using Green Hub Energy has many benefits, including reducing greenhouse gas emissions, decreasing air pollution, preserving water resources, and creating job opportunities in renewable energy industries.

Countries are developing policies and programs to encourage the use of renewable and clean energy sources and promote environmental preservation to achieve the objectives of Green Hub Energy

2.6. Resource energy building:

Denmark stands at the forefront of global efforts in harnessing renewable resources, particularly wind and solar energy, to achieve carbon neutrality and sustainability. The nation has effectively implemented national and international standards, aligning with EU regulations, and surpassing carbon reduction targets established in agreements such as the Paris Agreement. Although there are divergent opinions within Denmark regarding the economic implications of these commitments, the country's dedication to renewable energy systems is evident through the development of smart microgrids. These microgrids play a significant role in enhancing the sustainability of the electricity grid and district heating networks.

Furthermore, Denmark's district heating system is a cornerstone, efficiently providing warmth to Danish homes while effectively managing energy consumption. Wind turbines, solar farms, and biofuels constitute crucial sources of electricity for Danish consumers, solidifying Denmark's leadership in the adoption of renewable energy. The intelligentization of distribution and super-distribution networks in Denmark, facilitated by smart meters and the impactful role of social media in shaping consumption patterns, successfully bridges the gap between production and consumption in the renewable resources sector.

Denmark's journey toward sustainable energy exemplifies a successful amalgamation of national and global standards, innovative technologies, and public participation. The focus remains on reducing the carbon footprint while ensuring stability and energy efficiency. Despite differing opinions among parties in parliament, Denmark, regarding the economic impact of these initiatives, the country continues to serve as a model for creating a greener and more sustainable future.

Chapter 3 Produktion

3.1 Produktion:

Details on our production department's use of advanced software to simulate solar systems. Through this process, we can model different orientations and angles to determine the best setup for a solar farm at the project site. After careful evaluation, we chose PVsyst-7 as the most suitable software for our needs. We conducted simulations for five scenarios, beginning with the selection of weather data from reputable sources. In the first three scenarios, we focused on determining optimal placement angles for the solar panels based on the project's geography. In the remaining scenarios, we incorporated a storage system and consumption profiles to analyze the system's behavior and assess battery requirements, as well as economic considerations for future stages of the project:

1. Situation of PV.
2. System information.
3. Result.
4. Tilt.
5. Horizon profile.
6. Daily input and output diagram.
7. Performance ratio (PR).
8. System output power distribution.
9. Array temperature Vs. Effective irradiance.
10. Normalized production.
11. The loss diagram.
12. Single line diagram.

Scenario 1

Table2. Project Summary Scenario 1:

Situation
Latitude: 57.09°N
Longitude: 9.98°E
Altitude: 11m
Albedo: 0.20
Meto data: NASA-SSE

Table3. System Summary Scenario 1:

PV ARRAY
Nb. of modules: 1 unit.
Pnom total: 265 Wp.
INVERTERS:
Nb. of units: 1 unit.
Pnom total: 240 W.
Pnom ratio: 1.104

Table 4. System information Scenario 1:

PV filed orientation: Fixed plane.
Tilt/Azimuth 30°/0.
Near shading: No shading.

Site: Green hub house. AAU.
System Type: Grid-connected.
Simulation: 01/10 -12/31(Generic meteo data).

Produced Energy: 292.05 KWH/YEAR.
Specific production: 1102 KWH/KWP/YEAR.
Perf. ratio PR: 80.89%

Table 5. Pv arry Scenario 1:

PV modules: AS-PS6068-265/
MPP VOLTAGE: 31.1 V.
Nominal power: 0.27 KWP.
MPP current: 8.6 A.
Inventor: IQ7-60-x-INT (1panel input).
Inv. unit: 0.2 KW.
Nb. Of in 1.

Table 6. Main Result Scenario 1:

SYSTEM PRODUCTION: 292 KWH/YEAR.
SPECIFIC PROD.; 1102KWH/KWP/YEAR.
PERFORMANCE RATIO: 0.809.
NORMALIZED PROD: 3.02 KWH/KWP/DAY.
ARRAY LOSSES: 0.60 KWH/KWP/DAY.
SYSTEM LOSSES: 0.11 KWH/KWP/DAY

3.2. What Is Azimuth?

In a photovoltaic (PV) system, azimuth is the direction in which the solar panels are horizontally oriented. It's essential because it determines the angle at which the panels face the sun during the day. The proper placement of cells in the right direction increases power production. Azimuth adjustment varies based on geographical location and seasonal changes, allowing the installer to coordinate better with sunlight. Therefore, it plays a crucial role in productivity and energy production, which is why we mention it in the simulation of scenarios, and the results are shown.

In the field of photovoltaic (PV) simulation, "loss of optimum" refers to the reduction in performance or efficiency of a PV system relative to its optimal conditions. It's caused by various factors that affect the system's ability to convert sunlight into electricity. To address this issue, we adopted an installation strategy based on three assumptions in three initial scenarios where we haven't connected and aligned daily consumption with the solar cell grid. The assumptions consider that the consumer intends to use solar cells throughout the year, in winter, or during spring, based on the geographical location and climate of Denmark. To validate the suitability of these simulations, we examined the factors affecting the solar cell configuration, including mismatch losses as discussed in the battery connection and cell arrangement section, temperature losses, shading losses, angle losses, and inverter losses. You can look at table 7 for the balance and main results of scenario 1. The purpose of each simulation is to prove the selection of the optimal installation mode by considering the influencing factors.

Valuable insights were gathered from the utilization of this software and a simulated project location. We concluded that an installation angle of 68 degrees is optimal for maximum efficiency during the winter season. Similarly, an angle of 35 degrees is recommended for peak efficiency during the summer months. For those seeking year-round efficiency, an installation angle of 45 degrees is the most suitable option.

Figure 0.1 The best tilt for the year

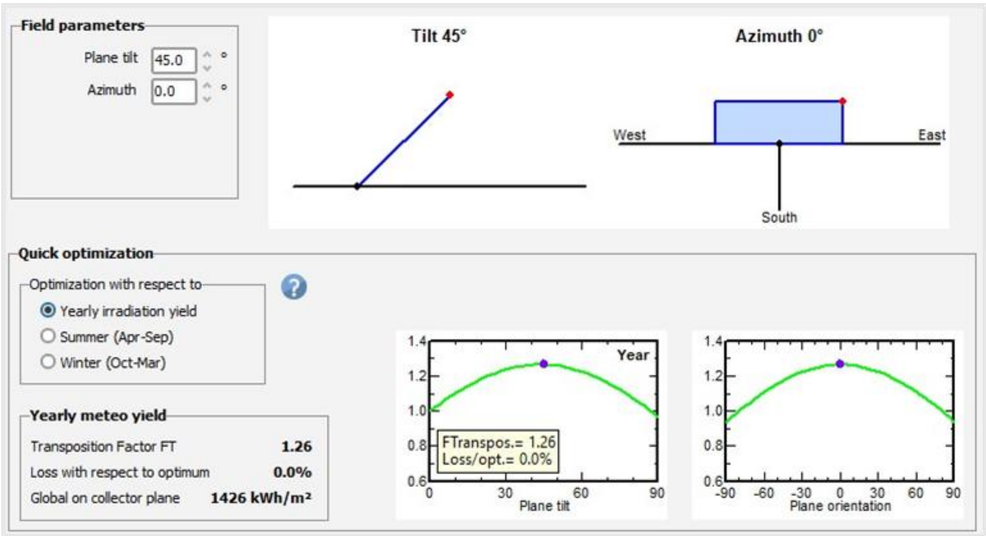


Figure 0.2 The best TILT for summer:

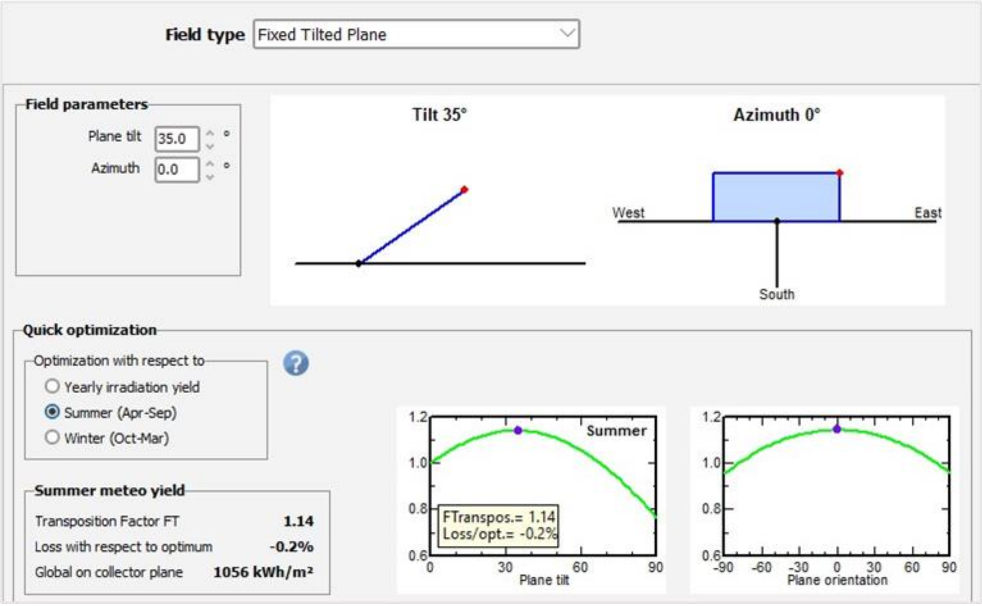
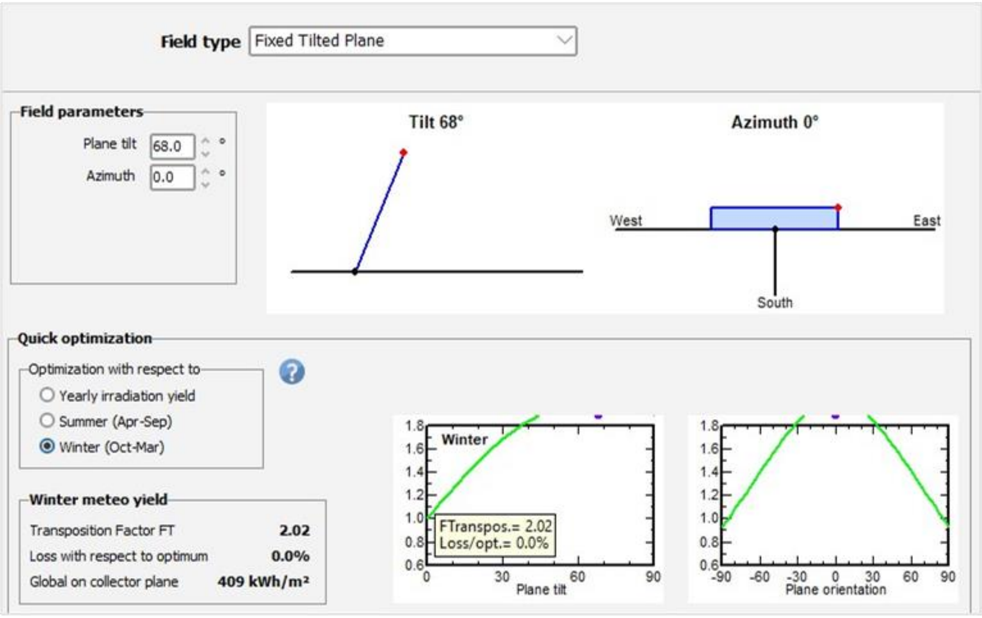


Figure 0.3 The best TILT for winter:



It is necessary to pay attention to this point in the simulation results. Our effort is that the best possible situation is to increase the amount of solar radiation and thus increase the system's output. Based on the optimal and global factors in the collector plate, it can be concluded that the installation strategy for the whole year has the best possible results, not the installation strategy for a limited period such as winter or summer. On the other hand, in the continuation of the results in the first 3 scenarios, you will see that the scenario installed at an angle of 45 degrees gets the best results when comparing all the factors mentioned in the analysis of the results of solar cells. Our goal is to increase the efficiency of the system and thus reduce the production of more carbon dioxide.

Global on collector plane for year , winter and summer are: 1426 KWh/ m^{2}, 1056KWh/ m^{2}, 409KWh/ m^{2}.

Table 7. Balances and main result for Scenario 1:

MONTH	GLOBHOR Kw/ m2	DIFFHOR KWh/ m2	T-AMB ^°C	GLOBLNC KWh/ m2	GLOBEFF KWh/ m2	E ARRAY kWh	G-GRID kWh	PR ratio
January	14.9	10.54	1.77	28.4	26.7	7.17	6.79	0.939
FEBRUARY	33.3	20.72	1.64	54.2	49.9	13.36	12.82	0.947
MARCH	77.2	43.71	2.94	106	95.4	25.09	24.19	0.930
APRIL	125.1	60.60	6.15	153.7	136.7	35.03	33.88	0.908
MAY	181	81.22	10.77	196.6	171.5	42.65	41.25	0.882
JUNE	189.3	82.50	14.17	195.5	169.9	41.46	40.08	0.865
JULY	192.2	80.91	16.61	204.9	177.1	42.74	41.34	0.856
August	148.5	69.44	16.82	171.3	151	36.66	35.43	0.860
September	90.3	68.80	13.44	118.6	105.6	26.26	25.33	0.877
October	46.2	27.90	9.72	70	63.6	16.40	15.74	0.911
November	20.11	13.80	5.51	36.8	36.8	9.80	9.34	0.938
December	11.2	8.06	2.87	23.4	23	6.21	5.86	0.949
YEAR	1129.3	546.20	8.58	1362.4	1207.2	302.82	292.05	0.889

Legends:

1. GlobHor: global horizontal irradiation.
2. DIFFHOR: diffuse irradiation.
3. T_Amb: Ambient Temperature.
4. GlobInc: Global incident in coll. plane.
5. GlobEff: Effective. Global, corr. for IAM and shading.
6. EArray: Effective energy at the output of the array.
7. E_Grid: Energy injected into the grid.
8. PR: PERFORMANCE Ratio.

3.3. Which factors have important roles in PV system analyses?

When studying a photovoltaic system (PV), there are several important factors to consider. Among the factors you mentioned, the following are especially relevant:

Horizon Index: The Horizon index understanding is important because it affects the shadows and obstacles that can affect the performance of a PV system. The horizon index helps to determine possible shade problems at different times of the day.

Daily input and output chart: This chart offers insights into the daily PV system production and energy consumption patterns, which are very important for optimizing the performance and correct size of its components.

Performance Ratio (PR): PR is a key criterion for evaluating the overall performance of a PV system. This energy compares the actual output of the system with its expected or theoretical output in optimal conditions and helps identify performance losses.

System Output Power Distribution: Understanding the distribution of electricity in the PV system, including the performance of separate panels or strands, can help identify problems and optimize energy production.

Array temperature vs. Effective radiation: Monitoring PV array temperature is important in relation to existing radiation for evaluating thermal performance and the effect of temperature on PV modules efficiency.

Normal production: Normal-produced data helps to calculate changes in climatic and environmental conditions and allows a more accurate comparison of PV system performance over time. Together Chart: A casualties diagram helps identify energy losses in the PV system, such as shade, soil, or electrical losses, which can guide efforts to improve system efficiency.

Single-line diagram: The single-line diagram provides a visual display of connections and electrical components in the PV system that helps to ensure proper design and maintenance.

Factors such as "cumulative collision distribution" and "daily output energy output voltage" do not appear to be directly related to PV system analysis and performance evaluation. They may be less related to the usual study of PV systems.

So, when studying a PV system, focusing on the factors related to performance, performance and its components is very important. Understanding daily and long-term performance, system losses, and configuration to optimize performance and reliability of PV system.

3.4. Horizon index in a photovoltaic (PV) system:

Horizon index in a photovoltaic (PV) system for several reasons:
Sun Position Calculation: The Horizon index helps to calculate the position of the sun during the day and throughout the year. This information is very important for PV systems because solar panels must be directed toward the sun to maximize energy production. Knowing the position of the sun, the system can adjust the slope and azimuth angle of solar panels for optimal exposure.
Shadow Analysis: Horizon view helps to analyze shade. Shading adjacent objects such as buildings, trees or other barriers can significantly reduce the efficiency of a PV system. Understanding the horizon view, can identify potential shadow issues and take steps to reduce them, such as shortening the trees or changing the position of solar panels.
Solar Access: Solar access refers to a part of the day when solar panels receive direct sunlight. The horizon index helps to calculate the duration of solar access in a particular location, which is essential for estimating energy production and measuring the PV system. Areas with longer solar access periods are usually more suitable for solar installations.
Seasonal Changes: The horizon also considers seasonal changes in the path of the sun. This is critical for designing PV systems that can constantly generate energy throughout the year. Seasonal settings for the slope and direction of solar panels can be done based on the horizontal specifications.
Energy Estimation: Careful awareness of the horizon index enables better estimation of the energy efficiency of a PV system. Considering the sun's path and possible shadows, designers and operators can predict the amount of energy produced by the system and contribute to financial planning and network integration.
Optimization of tracking systems: Some advanced PV systems use solar tracking systems that follow the sun's path to maximize energy absorption. The horizon index is essential to determine the timing and how these tracking systems are moved to be in line with the sun.
In short, the horizon profile is a vital factor in the design and performance of the PV system. Careful orientation and positioning enable solar panels, helps identify shade problems, and enables accurate anticipation of energy efficiency. All these factors contribute to the efficiency and effectiveness of a PV system. (Kreuwel, 2020)

Figure 0.4 Horizon profile for Scenario 1:

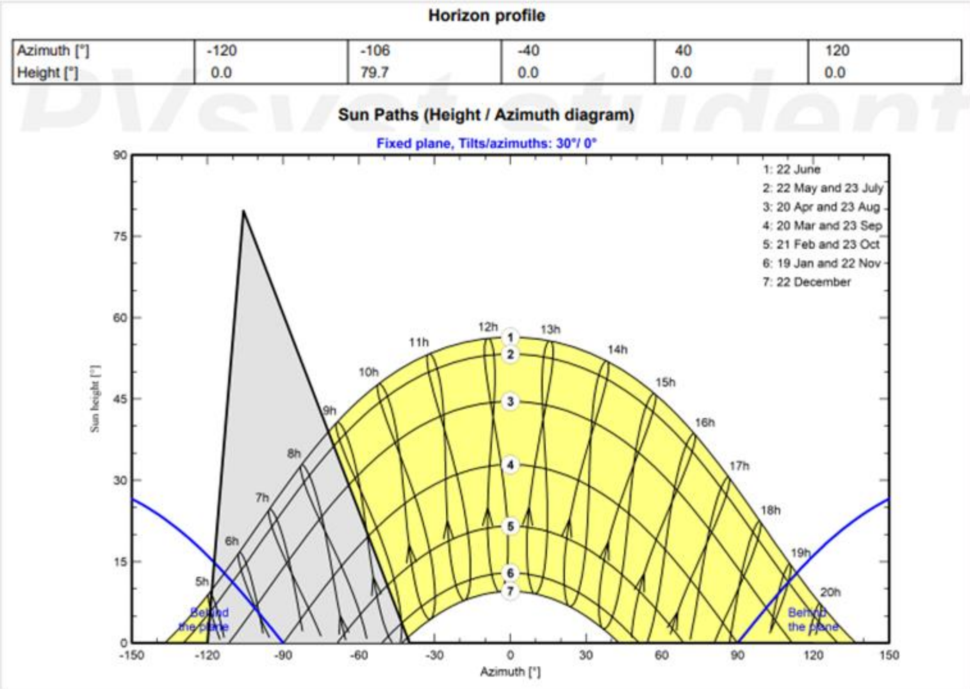
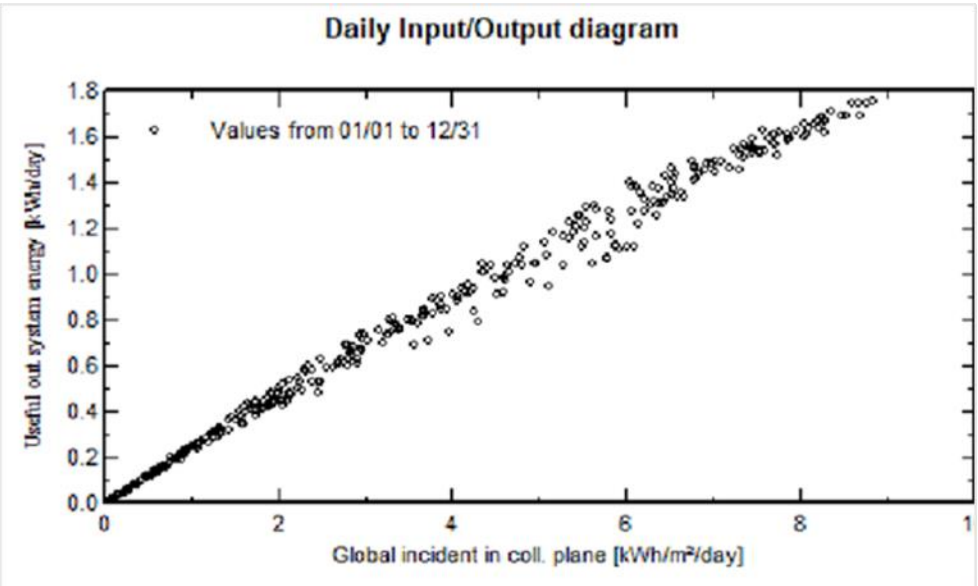


Figure 0.5 Daily input/output diagram:



The daily input/output graph serves as a highly effective simulator, offering valuable insights into the performance of a PV system. This simulation intricately captures the interplay between solar input and electrical output, providing a holistic understanding of energy dynamics crucial for system optimization and sustainable energy management.

In the context of scenarios 1.2 and 3, our primary objective with this simulation is to discern and meticulously document the direct correlation between the increase in solar energy intake and the subsequent rise in the system's output. By acknowledging this fundamental relationship, we can strategically enhance the roles of influencing factors. This enhancement involves the adept utilization of tools within the system, such as adjusting the inclination or azimuth angles, fine-tuning battery capacity, and optimizing Maximum Power Point Tracking (MPPT) mechanisms.

The versatility of the simulation empowers us to explore various scenarios and gauge the impact of different configurations, ensuring that our system is not only responsive to increased solar energy but also adaptable to dynamic environmental conditions. Through this iterative process, we aim to fine-tune the system's performance, maximizing its efficiency and reinforcing its role in sustainable energy solutions.

By actively engaging with the simulation results, we can iteratively refine our approach, making informed decisions about system adjustments and improvements. This iterative optimization, grounded in a deep understanding of energy dynamics, positions our PV system as a resilient and adaptable solution for harnessing solar energy and contributing to a more sustainable and eco-friendly energy landscape.

In scenario one, the analysis reveals a noteworthy trend as the transition is made from colder months to warmer ones. During this transition, there is a discernible increase in the amount of solar radiation received, not only in the vertical position but also in the overall total received from the surrounding environment.

This observation underscores the seasonal variability in solar radiation, with warmer months typically characterized by a more significant influx of sunlight. The increase in solar radiation, both directly received on the vertical plane and from the entire environment, is a crucial factor influencing the overall performance of the photovoltaic system.

Understanding and documenting these seasonal variations are essential for optimizing the system's energy output. It provides valuable insights into the dynamic nature of solar energy availability, enabling strategic adjustments and enhancements to the system configuration. By acknowledging and leveraging this seasonal variation, we can devise strategies to maximize the system's efficiency and output during periods of increased solar radiation, contributing to a more robust and responsive photovoltaic solution.

3.5. The role of performance PR in our calculation:

The Performance Ratio (PR) holds significant importance in photovoltaic systems (PV) for various compelling reasons:

System Performance Assessment: PR serves as a reliable indicator of how effectively a PV system converts sunlight into electricity. It evaluates the overall system performance by comparing the actual energy output to the theoretically expected output under ideal conditions. A high PR signifies efficient system operation that meets performance expectations. (https://theprgenius.com/what-is-performance-pr, 2023)

Troubleshooting: Continuous PR monitoring enables the detection of problems and faults within the PV system over time. A sudden drop in PR can signal issues such as module degradation, soiling (dirt or dust accumulation on panels), shading, or inverter malfunctions. Early detection allows for timely maintenance, minimizing energy losses.

Maintenance Planning: PR data aids in devising maintenance schedules. Regular PR monitoring helps system operators identify when panels or components require cleaning, repair, or replacement. This proactive approach maximizes system uptime and energy production.

Performance Benchmarking: PR serves as a benchmark for comparing the performance of different PV systems or individual components (e.g., solar panels, inverters) within a system. This benchmarking assists in evaluating the effectiveness of various technologies and designs, facilitating informed decisions for future installations or upgrades.

Accurate Energy Yield Estimation: PR plays a pivotal role in accurately estimating the energy efficiency of a PV system. This estimation is invaluable for project planning, financial modeling, and assessing the return on investment (ROI) of the system. It empowers stakeholders to make informed decisions regarding the project's viability.

Financial Implications: PR directly impacts the financial aspects. A higher PR implies that the PV system generates more electricity relative to its capacity, leading to increased revenue from energy sales or reduced electricity costs. Conversely, a lower PR may result in reduced income and potentially affect the project's financial feasibility.

Quality Control: During PV system installation, PR measurements serve as a quality control tool, ensuring that the system performs as expected and that all components function correctly. Deviations from expected PR values trigger further inspections and adjustments.

Operational Efficiency: PR is a crucial parameter for evaluating the operational efficiency of PV systems. Through continuous PR monitoring, system operators can optimize system performance by adjusting parameters such as panel orientation, cleaning schedules, and maintenance routines to maximize energy production.

Environmental Impact: High PR values indicate efficient energy generation, leading to reduced environmental impact. PV systems with higher PRs produce more clean energy, helping to lower greenhouse gas emissions and combat climate change.

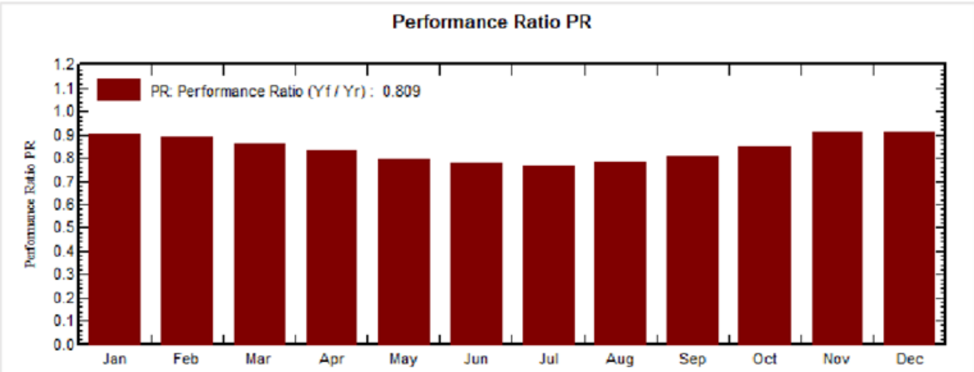
In summary, the Performance Ratio (PR) is a vital performance criterion in PV systems. It provides insights into system efficiency, aids in identifying maintenance needs and errors, informs financial decisions, and contributes to the environmental sustainability of renewable energy generation. PR serves as a valuable tool for both system operators and stakeholders involved in PV projects.

Why do we need figure number 3-6?

Figure understanding:

Figure 3-6 describes Performance ratio (PR), which is an important measure that affects the entire life cycle of a PV system, from its design and implementation to continuous monitoring. PR ensures that the system is optimized for maximum performance under real-world conditions while considering various environmental variables that may affect its performance. We use PR to analyze different scenarios and measure the combined effects of environmental and technical factors on production rates. By examining these scenarios, we can confirm our installation strategy and determine the azimuth angle. This scrutiny helps us determine if our installation strategy, based on seasonal operations during the winter or spring, is effective or needs to be adjusted. According to the result, it can be said that this scenario based on simulation has the maximum efficiency of about 81percent.

Figure 0.6 Performance ratio PR:



Based on the simulation graph, the system's average performance throughout the year is approximately 0.809. The highest efficiency is recorded in November and December, reaching around 0.92, while the lowest efficiency of about 0.83 is observed in July. These values are indicative of the system's performance and efficiency under various factors and favorable production conditions.

3.6. System output power distribution:

The distribution of power output in a photovoltaic system (PV) refers to how the electrical energy generated within the system is allocated or spread out. This distribution can vary and is influenced by various factors, including the configuration of the PV system, environmental conditions, and system design. Here are some key aspects of power output distribution in a PV system:

Distribution at the Panel Level: In a typical PV system, the power output initially occurs at the level of individual solar panels. When exposed to sunlight, each solar panel generates direct current (DC) electricity. The combined power output of these individual panels contributes to the overall energy production of the system.

Conversion by Inverters: The DC electricity produced by the solar panels is then directed to inverters, which convert it into alternating current (AC) electricity. Inverters play a critical role in distributing the power output effectively, ensuring that the electricity generated is compatible with the electrical grid or the devices within a building.

Array-Specific Distribution: In cases where a PV system comprises multiple strings or arrays of solar panels, each array can have its unique power output. Factors like varying orientations or tilt angles of these arrays can affect their individual energy generation. The collective power output of all arrays contributes to the overall system output.

Temporal Distribution: Power output in a PV system fluctuates throughout the day and across different seasons. Typically, it follows a bell-shaped curve, with peak output occurring around solar noon when sunlight intensity is the highest. Output diminishes in the morning and afternoon. Seasonal changes also impact energy production, with more generated in summer compared to winter.

Environmental Impact: Various environmental factors, such as shading, cloud cover, and temperature, can influence power output distribution. Shading from nearby objects like trees or buildings can significantly reduce the output of specific panels or arrays. Cloud cover temporarily diminishes electricity generation, while high temperatures can affect panel efficiency.

Solar Tracking Systems: Advanced PV systems may employ solar tracking systems that follow the sun's path to maximize energy absorption. These systems adjust the orientation of panels throughout the day to capture more sunlight, optimizing power output.

Energy Storage Considerations: In PV systems equipped with energy storage, a portion of the power output is directed towards charging batteries or other energy storage devices. This stored energy becomes valuable during periods of low sunlight or during nighttime, providing a more consistent power supply.

Grid Interaction: PV systems connected to the electrical grid can feed excess power back into the grid when they generate more electricity than is consumed locally. This surplus energy can be credited or sold to the utility company, contributing to the overall power supply of the grid.

Why do we need figure 3.7?

Figure understanding:

How does the design and calculation of this factor benefit us, and why is it important? This figure, a product of simulating scenario number 1, provides us with several key advantages:

Identification of Optimal Angles:

The figure allows us to identify the angles that yield the highest output power. By analyzing data for each day of the year, we gain insights into the influence of azimuth on power generation.

Accurate inverter sizing and arrangement:

This factor enhances the precision in arranging and determining the size of the inverter. It ensures a more suitable selection of the inverter, aligning with the production rate of the system and optimizing its efficiency.

Battery Sizing for Energy Storage:

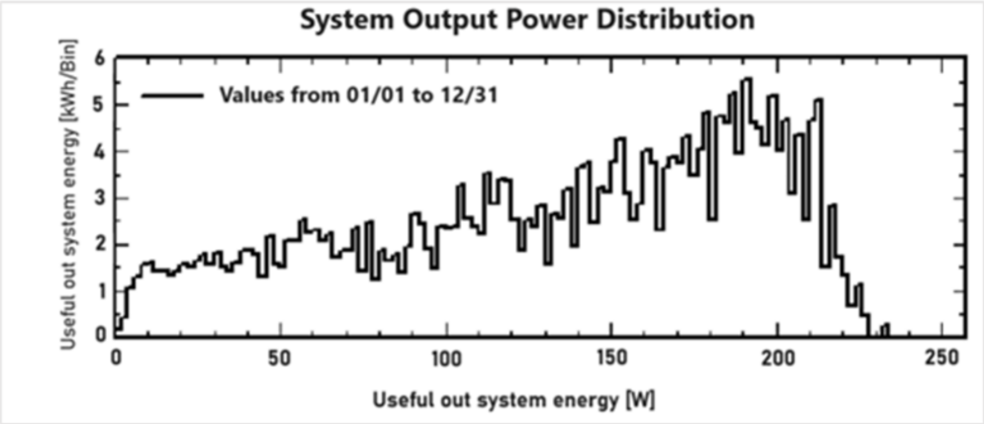
Utilizing both consumption and production data, particularly evident in scenarios 4 and 5, aids in a clearer comparison. This information guides the selection of an appropriately sized and powered battery, considering peak demand times and stored energy requirements.

Impact on Economic Estimation:

This factor, influenced by the outcomes highlighted in the previous three points, directly affects the economic estimation of our system. Accurate equipment selection translates to capital savings, thereby impacting the return on investment positively.

In summary, the design and calculation of this factor play a pivotal role in optimizing various aspects of the PV system. It not only guides the physical arrangement and tilt of solar panels but also contributes to the accurate sizing of inverters and batteries. The economic implications are significant, as a well-designed system ensures efficient energy production, storage, and utilization, resulting in enhanced capital efficiency and a positive return on investment

Figure 0.7 System output power distribution:



The diagram illustrates the direct impact of the solar system's efficiency on the energy output for the consumption of electrical devices and the energy stored in batteries. As depicted in the graph, higher levels of received radiation led to increased energy output for both network consumption and battery storage. This correlation highlights the crucial role of system efficiency in maximizing the utilization of solar energy, particularly on days with elevated radiation levels. (increase from day number 90 to 220-but maximum days are:110-120-150-190-220)

3.7. Array temperature versus effective irradiance:

In the realm of photovoltaic (PV) solar systems, the "temperature coefficient" is a widely used term that describes the correlation between a solar panel array's temperature and the solar energy it receives. To grasp this concept fully, it's essential to define the key components involved.

Firstly, the array temperature (also called module temperature) refers to the temperature of the solar panel array or individual panels within it. This factor is critical to PV systems as any fluctuations in operational temperature can have a significant impact on panel performance, leading to reduced efficiency and potentially shortened lifespans.

Secondly, effective irradiance is the amount of solar energy that reaches the panels and can be converted into electricity. Factors such as shading, contaminants, and the angle of sunlight can affect the amount of sunlight reaching the panels, and thus, effective irradiance.

The interplay between array temperature and effective irradiance is crucial when analyzing and modeling solar panels. Understanding how temperature fluctuations impact a panel's output under varying levels of effective irradiance is fundamental to designing and optimizing PV systems.

To simplify these calculations, manufacturers of solar panels and PV system designers often provide temperature coefficients. These coefficients help estimate a panel's performance under different environmental conditions, making it easier to design, optimize, and maintain solar panel arrays.

Why do we need figure 3.8?

Figure understanding:

A figure showing array temperature versus effective irradiance is critical in understanding the performance characteristics of your photovoltaic (PV) system. Here's how to use it in your project:

Figure understanding:

1- It shows the temperature of the solar panel array.

2- The effective radiation shows the amount of radiation received by the panel.

3- It shows the effect of temperature on the performance of the panel.

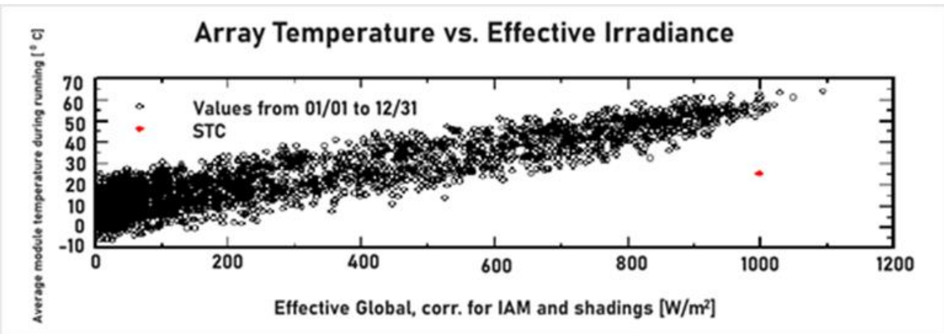
4- It plays a role in calculating and estimating the efficiency of the solar panel based on the influence of environmental factors.

In summary, the figure of array temperature versus effective irradiance is a valuable tool to optimize PV system design and performance considering factors such as temperature sensitivity and actual sunlight conditions. This enables informed decision-making at the design stage and helps predict system performance in the real world.

This diagram illustrates the correlation between the rise in surface temperature of the cells and their efficiency. It serves as a highly impactful simulation, aiming to maximize received radiation while concurrently selecting an optimal design to mitigate the increase in cell surface temperature. This preventive action is crucial, as elevated temperatures can lead to accidents, diminishing system efficiency and output.

In the simulation for this specific scenario, precisely demonstrates that as we transition towards warmer months, the factor of increased temperature becomes more pronounced. Subsequently, the trend stabilizes before reaching its final resolution. This dynamic showcases the importance of addressing temperature concerns in solar cells, emphasizing the need for strategic designs to maintain system efficiency and overall performance.

Figure 0.8 Array temperature vs. Effective irradiance:



3.8. Normalized production:

Production data normalization is the process of standardizing data to understand changes or factors that may affect the output of a system or a production process. Therefore, in the production process, energy production and data analysis are used to compare and understand the production data.

The purpose of normalization is to remove the effects of extraneous factors so that production data can be compared or analyzed more accurately. This is achieved by defining a baseline or reference point and, as a result, scaling or adjusting production data based on that reference point. The normalization process can include various factors such as time, capacity, environmental conditions, performance, and factors outside the production set.

Normal production data provides a better and clearer picture of the performance of a system or process and accelerates the identification of trends, anomalies, and consequently areas for improvement. It is a valuable tool for performance analysis, benchmarking, and informed decision-making in various areas.

(https://www.pvsyst.com/help/performance_index.htm, 2020)

What is the reason for us to need figure 3.9?

Understanding figure?

Understanding normal production:

Normalized output provides a measure of how efficient a PV system is relative to its expected or rated performance.

It considers the effect of external factors such as shade and weather on the efficiency of the system.

Use in project analysis:

When designing a PV system, it is necessary to estimate and predict its energy output in different scenarios.

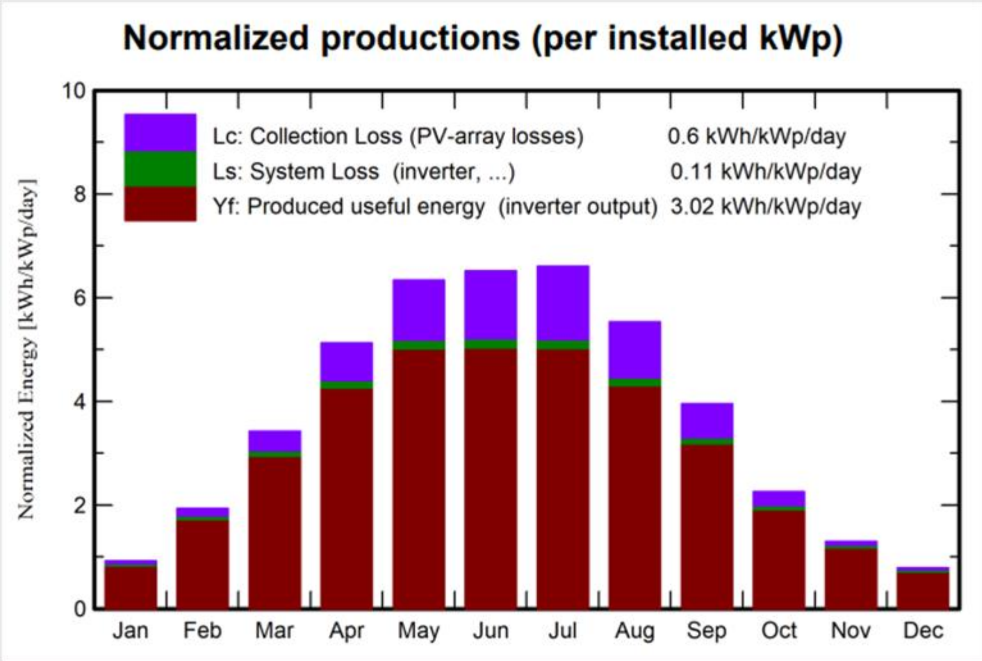
Normal production helps us to check the output of the system under ideal conditions with real conditions. Also, by knowing the normal production, we can reconsider the network design and connection method and consider the most suitable mode of connecting the arrays to produce more power.

Also, knowing and simulating normal production can play an important role in defining the angle of inclination and azimuth, because by changing this angle and of course changing the output of the system, we know which scenario is more suitable for us. These comparisons were made at the end of scenario number 3.

On the other hand, even after exploitation, this factor helps us to maintain suitable and ideal conditions for maximum production.

In short, normal production figures are essential for designing, analyzing and optimizing your PV system. They provide a quantitative basis for decision-making throughout the project lifecycle and ensure that your system is operating effectively and meeting or exceeding expected performance levels.

Figure 0.9 Normalized production (per installed Kwp)



This simulation holds significance as it provides insights into both the system's output from the inverter and the simulated losses within the plates and the overall system. By leveraging this simulation, we can enhance our success in achieving an optimal design and effective energy management.

In this specific scenario, the output energy from the inverter is measured at 3.02 kWh/Kwp/day. Additionally, the simulation indicates that approximately 6 kWh/Kwp/day of energy is wasted in the cells, and about 0.11 kWh/Kwp/day is lost in the overall system. These values offer valuable data for fine-tuning the system, minimizing losses, and maximizing energy efficiency.

3.9. Why loss diagram is important in PV system?

The loss chart is an important tool for financial analysis. By knowing the efficiency and the number of losses in the system, you can easily analyze and calculate the efficiency of a solar cell system and determine its economic efficiency. Therefore, at the time of the contract for the supply of power and equipment, you can have a better perspective with the companies. And the groups negotiated.

To make informed financial decisions about a PV project, an accurate loss assessment is essential. It allows you to determine the economic viability of the project, estimate the return on investment (ROI) and predict the payback period.

Continuous performance monitoring is critical to ensure the efficiency and reliability of a PV system. This will help you identify any potential problems or performance degradation over time, such as those caused by aging or surrounding structures.

In general, the efficiency diagram of a PV system provides a comprehensive view of the energy losses at the site. This information is critical to optimizing system performance, troubleshooting problems, improving system design, and making informed financial evaluations. Whether you're working on a residential, commercial, or industrial application, understanding loss charts and performance monitoring is essential to success.

What is the purpose of a loss diagram?

Understanding figure 3.10?

Simulating this factor yields the following outcomes:

Identification of Detrimental Factors:

The simulation helps identify factors that contribute to increased losses in the solar panel system. Understanding these detrimental elements is crucial for system optimization.

Mitigation of Negative Impact:

By simulating this factor, we can effectively mitigate the impact of harmful factors. This includes adjustments to the angle of inclination, azimuth, and the selection of an appropriate inverter.

Economic Considerations:

The choice of inverter and the implementation of various scenarios are assessed from an economic standpoint. Each scenario is justified based on financial considerations, allowing for estimations and predictions of the economic viability of each proposed scenario.

Figure 0.10 The Loss Diagram for SCENARIO

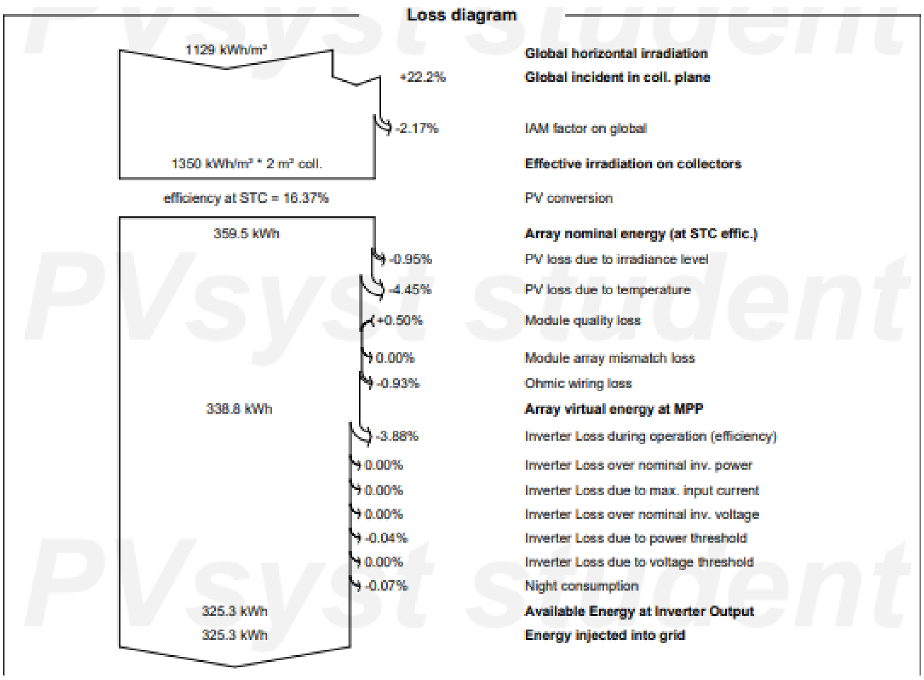
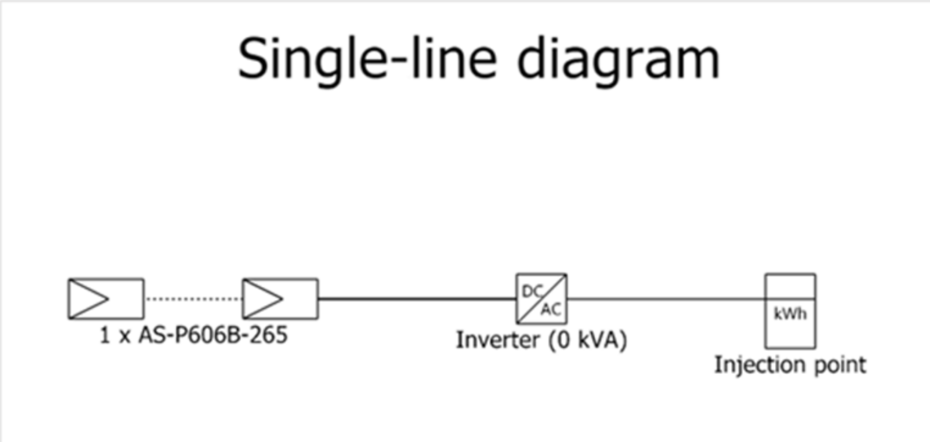


Figure 0.11 Singel-line diagram



Scenario 2:

As mentioned in the explanation of scenario #1, the formula of our strategy for the use of solar cells revolves around whether the plan fulfills the whole year or specifically targets one of the spring or winter seasons. Assuming the use of these cells throughout the year, we have drawn scenarios 1, 2 and 3.

In scenario #1, we carefully defined the key factors before reviewing the results and clarifying the significance of the simulation results. Moving forward, we now begin to define and simulate scenario #2 with the following parameters:

The performance of this system is predicted for the whole year and every day.

The Tilt/azimuth set for this scenario is set to 45degrees.

Also, below is a summary of the simulated results for each of the factors obtained in scenario 1.

Table 8. Summary of the simulated results for each of the factors obtained in scenario 1.

factors	Scenario 1
latitude	57.09
longitude	9.98
Pv field orientation	FIXED
Tilt/azimuth	30/0
Number of modules	1 UNIT
Pnom total	240 W
Production energy	292.05 kwh /kwp/year
Specific production	1102 kwh/kwp/year
Perf. ratio PR	80.89%
NORMALIZED PROD	3.02kwh/kwp/day
ARRAY LOSSES	0.60 kwh/kwp/day
SYSTEM LOSSES	0.11 kwh/kwp/day

Table. 9. Project Summary scenario2:

Situation
Latitude: 57.02°N
Longitude: 9.98°E
Altitude: 11m
Albedo: 0.20
Meto data: NASA-SSE

Table 10. System Summary Scenario 2:

PV filed orientation: Fixed plane.
Tilt/Azimuth 45°/0.
Near shading: No shading.

Table 11. System Information Scenario 2:

PV ARRAY
Nb. of modules: 1 unit.
Pnom total: 265 Wp.
INVERTERS:
Nb. of units: 1 unit.
Pnom total: 300 W.
Pnom ratio:0.883

Table 12. Result Summary Scenario 2:

Produced Energy: 325.07 KWH/YEAR.
Specific production: 1227 KWH/KWP/YEAR.
Perf. ratio PR: 88.89%

Site: Green hub house. AAU.
System Type: Grid-connected.
Simulation: 01/10 -12/31(Generic meteo data).

Table 13. PV array Scenario 2:

PV modules: AS-PS6068-265/
MPP VOLTAGE: 31.1 V.
Nominal power: 0.27 KWP.
MPP current: 8.6 A.
Inventor: MS300 MICROINVERTER (1panel input).
Inv. unit: 0.3 KW.
Nb. Of in 1.

Table 14. Main Result Scenario 2:

SYSTEM PRODUCTION: 325 KWH/YEAR.
SPECIFIC PROD.; 1227KWH/KWP/YEAR.
PERFORMANCE RATIO: 0.889.
NORMALIZED PROD: 3.36 KWH/KWP/DAY.
ARRAY LOSSES: 0.28 KWH/KWP/DAY.
SYSTEM LOSSES: 0.14 KWH/KWP/DAY

Table 15. Balances and main results Scenario 2:

MONTH	GLOBHOR Kw/m²	DIFFHOR KWh/m²	T-AMB ^°C	GLOBLNC KWh/ m²	GLOBEFF KWh/ m²	E ARRAY kWh	G-GRID kWh	PR ratio
January	14.9	10.54	1.77	28.4	26.7	7.17	6.79	0.902
FEBRUARY	33.3	2072	1.64	54.2	49.9	13.36	12.82	0.893
MARCH	77.2	43.71	2.94	106	95.4	25.09	24.19	0.861
APRIL	125.1	60.60	6.15	153.7	136.7	35.03	33.88	0.832
MAY	181	81.22	10.77	196.6	171.5	42.65	41.25	0.792
JUNE	189.3	82.50	14.17	195.5	169.9	41.46	40.08	0.773
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Legends:

1. GlobHor: global horizontal irradiation.
2. DiffHor: horizontal diffuse irradiation.
3. T_Amb: Ambient Temperature.
4. GlobInc: Global incident in coll. plane.
5. GlobEff: Effective. Global, corr. for IAM and shading.
6. EArray: Effective energy at the output of the array.
7. E_Grid: Energy injected into the grid.
8. PR: PERFORMANCE Ratio.

Figure 0.12 Horizon Profile for Scenario 2:

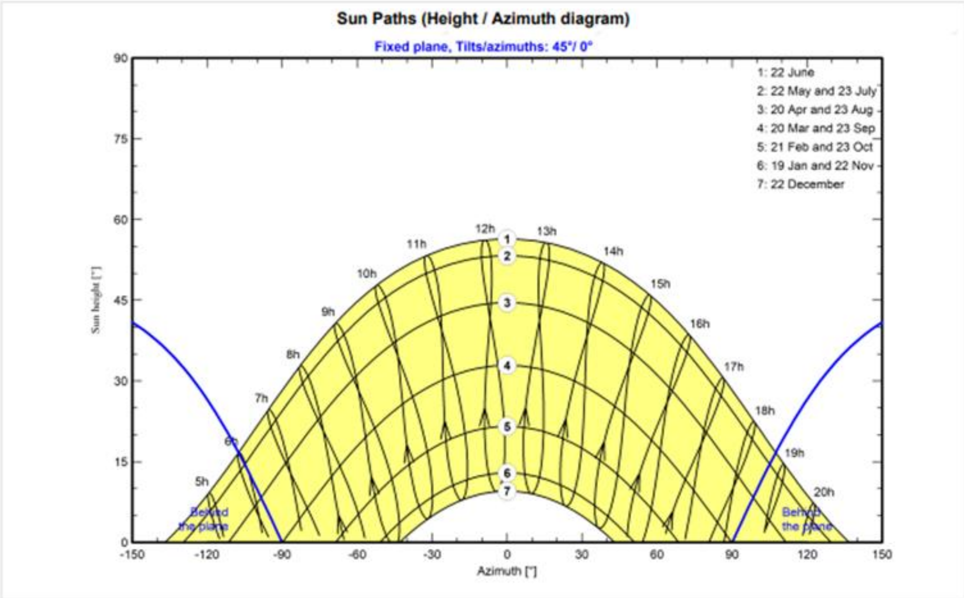
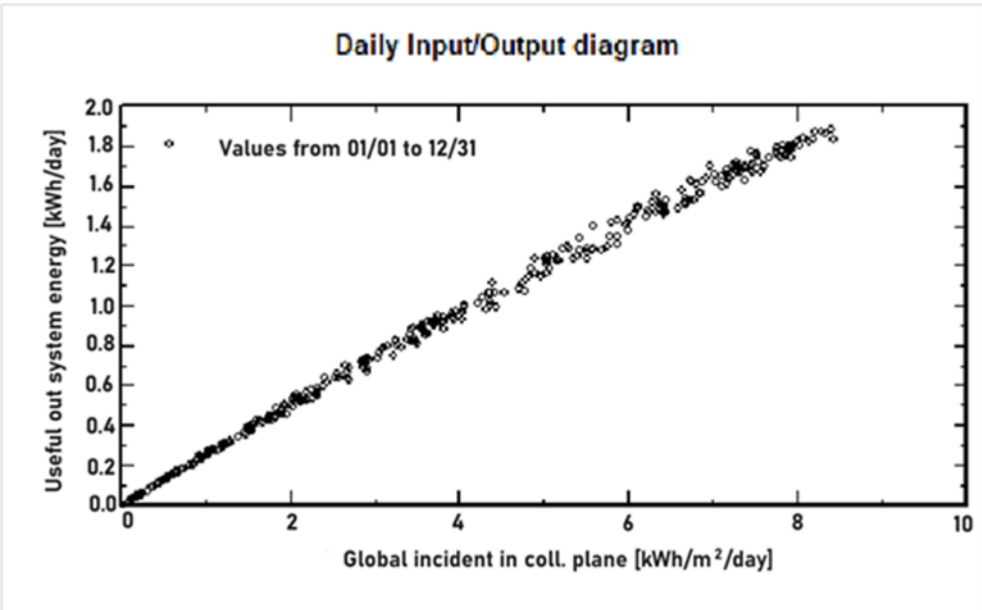


Figure 0.13 Daily input /output diagram:

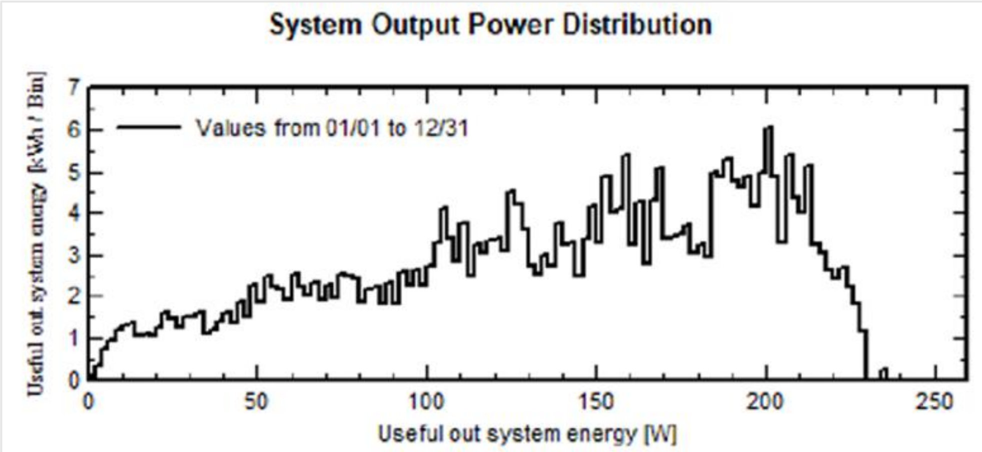


In scenario two, the analysis reveals a noteworthy trend as the transition is made from colder months to warmer ones. During this transition, there is a discernible increase in the amount of solar radiation received, not only in the vertical position but also in the overall total received from the surrounding environment.

This observation underscores the seasonal variability in solar radiation, with warmer months typically characterized by a more significant influx of sunlight. The increase in solar radiation, both directly received on the vertical plane and from the entire environment, is a crucial factor influencing the overall performance of the photovoltaic system.

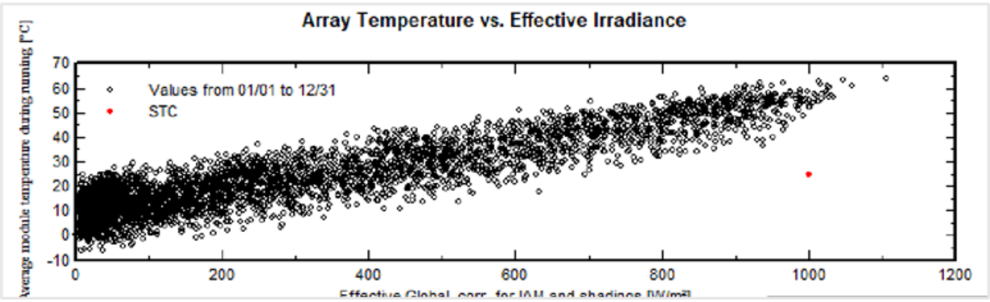
Understanding and documenting these seasonal variations is essential for optimizing the system's energy output. It provides valuable insights into the dynamic nature of solar energy availability, enabling strategic adjustments and enhancements to the system configuration. By acknowledging and leveraging this seasonal variation, we can devise strategies to maximize the system's efficiency and output during periods of increased solar radiation, contributing to a more robust and responsive photovoltaic solution.

Figure 0.14 System output power distribution:



The diagram illustrates the direct impact of the solar system's efficiency on the energy output for the consumption of electrical devices and the energy stored in batteries. As depicted in the graph, higher levels of received radiation led to increased energy output for both network consumption and battery storage. This correlation highlights the crucial role of system efficiency in maximizing the utilization of solar energy, particularly on days with elevated radiation levels. (increase from day number 110 to 210-but maximum days are:110-125-150-200-210)

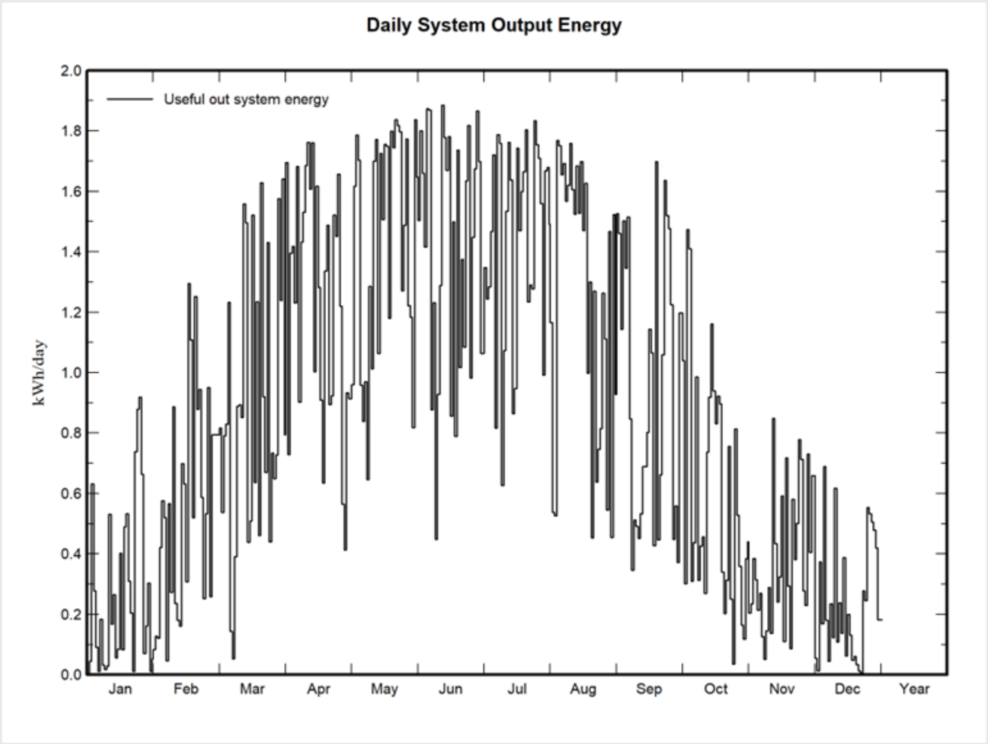
Figure 0.15 Array temperature vs. Effective irradiance:



This diagram illustrates the correlation between the rise in surface temperature of the cells and their efficiency. It serves as a highly impactful simulation, aiming to maximize received radiation while concurrently selecting an optimal design to mitigate the increase in cell surface temperature. This preventive action is crucial, as elevated temperatures can lead to accidents, diminishing system efficiency and output.

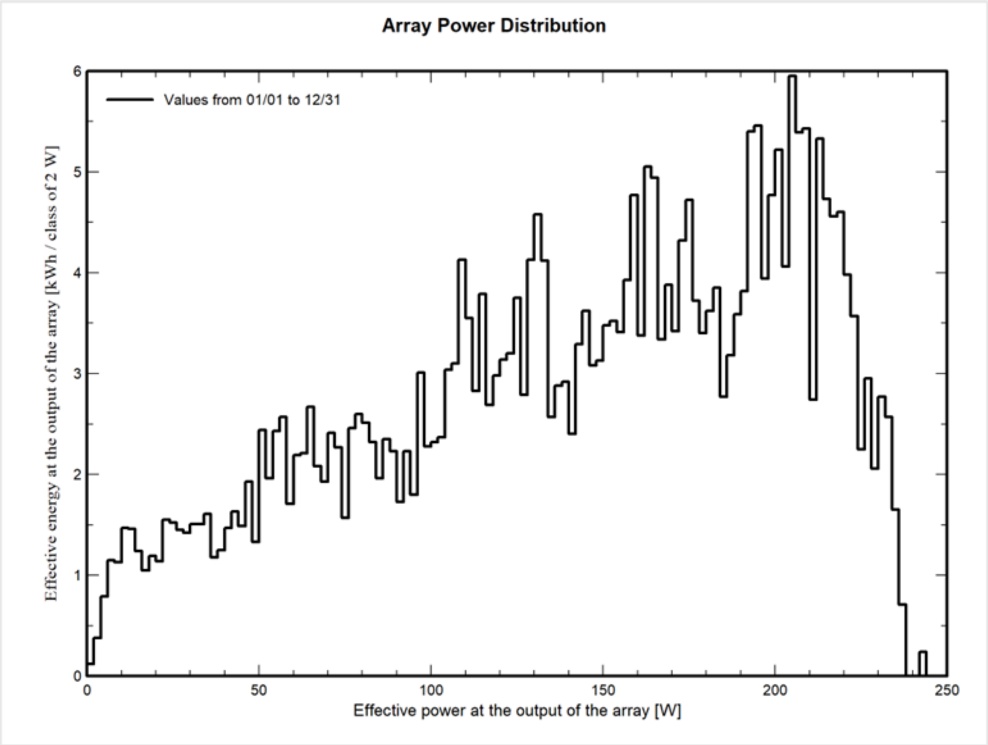
In the simulation for this specific scenario, precisely demonstrates that as we transition towards warmer months, the factor of increased temperature becomes more pronounced. Subsequently, the trend stabilizes before reaching its final resolution. This dynamic showcases the importance of addressing temperature concerns in solar cells, emphasizing the need for strategic designs to maintain system efficiency and overall performance.

Figure 0.16 Daily system output energy:



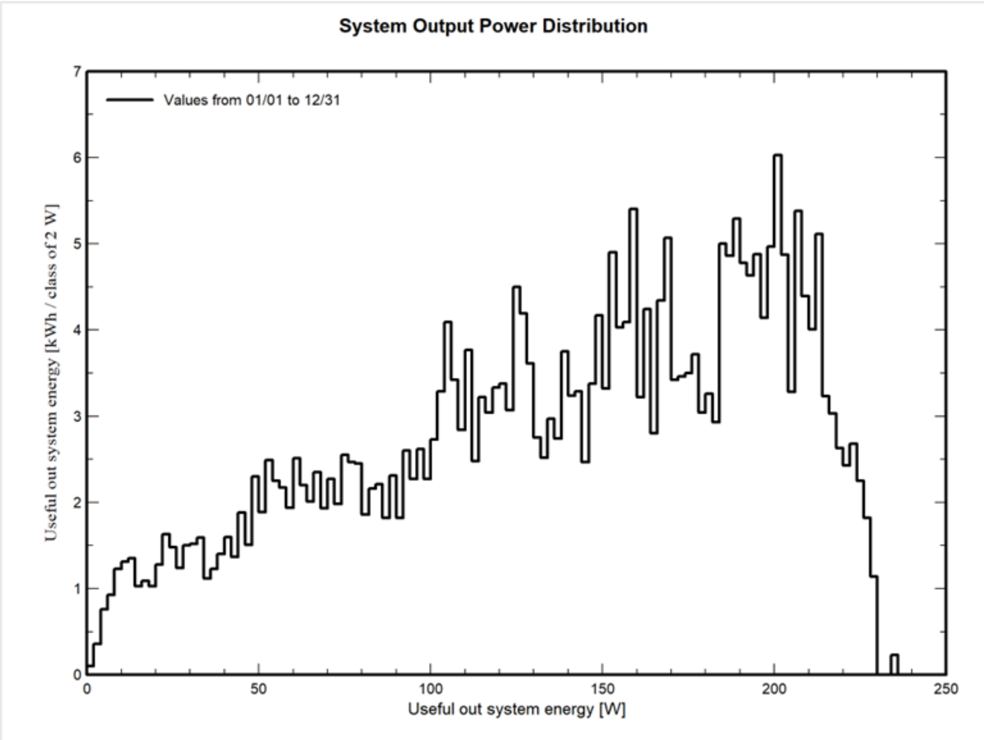
In this diagram, the correlation between the rise in temperature and the increase in radiation is evident, showcasing a corresponding increase in output and, consequently, the efficiency of the design. According to this simulation, the optimal range for daily production spans from March to mid-October. This insight is valuable for understanding the seasonal variations in the system's performance and aids in determining the most productive periods for energy generation.

Figure 0.17 Array power distribution:



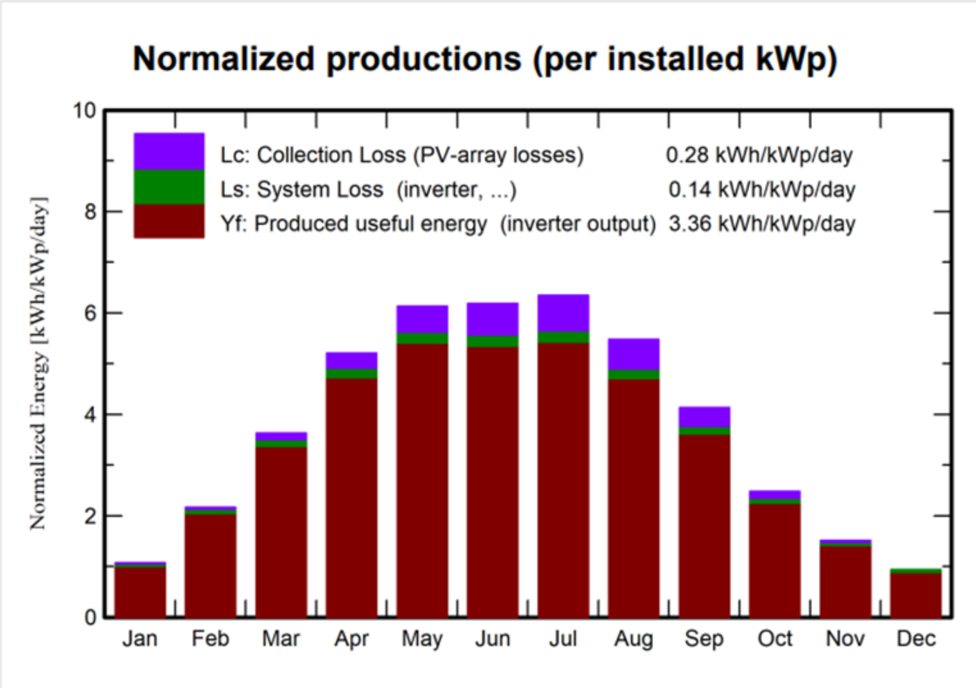
Based on the previously provided diagram and explanations, considering influential environmental factors and the role of control equipment, it can be inferred that as temperature rises and solar panel radiation increases, the effective power output from the arrays demonstrates a proportional increase, resulting in a corresponding rise in the overall energy output from the entire system. This relationship is direct and indicates a positive correlation between environmental conditions, array power output, and system energy generation. This increase continues from day 50 to day 240.

Figure 0.18 System output power distribution:



The increase in system output also has an upward trend from 50 to 240 days.

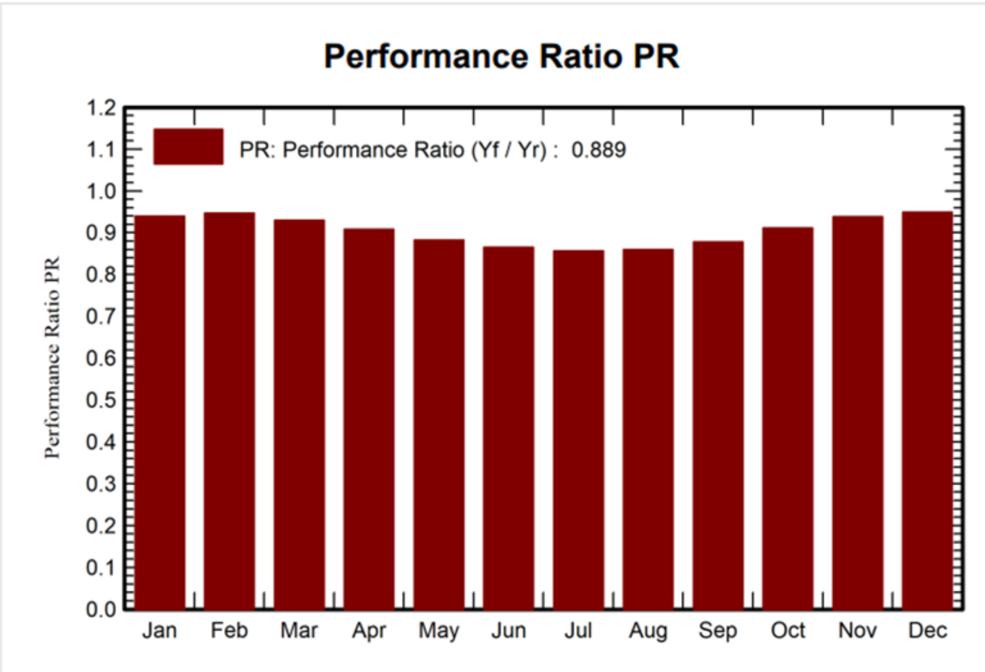
Figure 0.19 normalized production (per installed KWp)



This simulation holds significance as it provides insights into both the system's output from the inverter and the simulated losses within the plates and the overall system. By leveraging this simulation, we can enhance our success in achieving an optimal design and effective energy management.

In this specific scenario, the output energy from the inverter is measured at 3.36 kWh/Kwp/day. Additionally, the simulation indicates that approximately 0.28 kWh/Kwp/day of energy is wasted in the cells, and about 0.14 kWh/Kwp/day is lost in the overall system. These values offer valuable data for fine-tuning the system, minimizing losses, and maximizing energy efficiency.

Figure 0.20 performance ratio pr:



Performance ratio (PR), which is an important measure that affects the entire life cycle of a PV system, from its design and implementation to continuous monitoring. PR ensures that the system is optimized for maximum performance under real-world conditions while taking into account various environmental variables that may affect its performance. We use PR to analyze different scenarios and measure the combined effects of environmental and technical factors on production rates. By examining these scenarios, we can confirm our installation strategy and determine the azimuth angle. This scrutiny helps us determine if our installation strategy, based on seasonal operations during the winter or spring, is effective or needs to be adjusted. According to the result, it can be said that this scenario based on simulation has the maximum efficiency of about 89 percent.

Figure 0.21 The loss diagram for scenario 2:

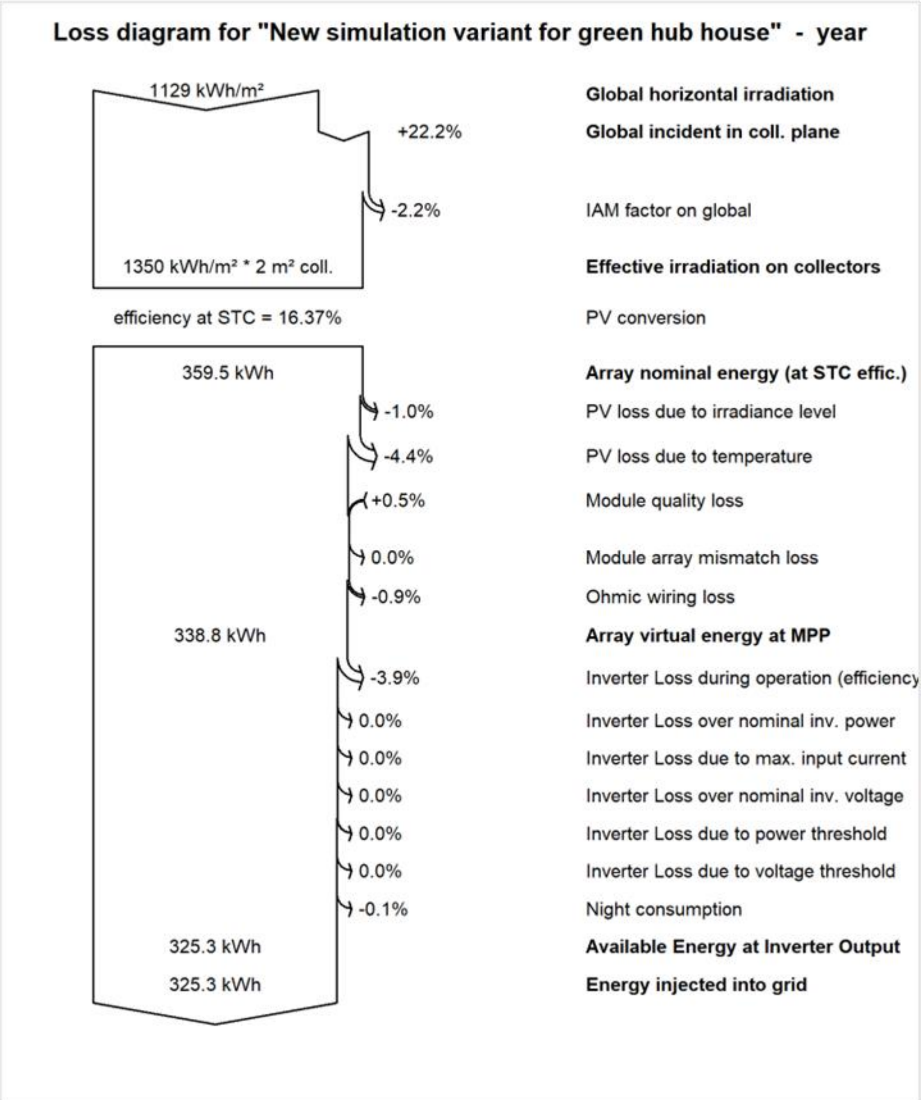
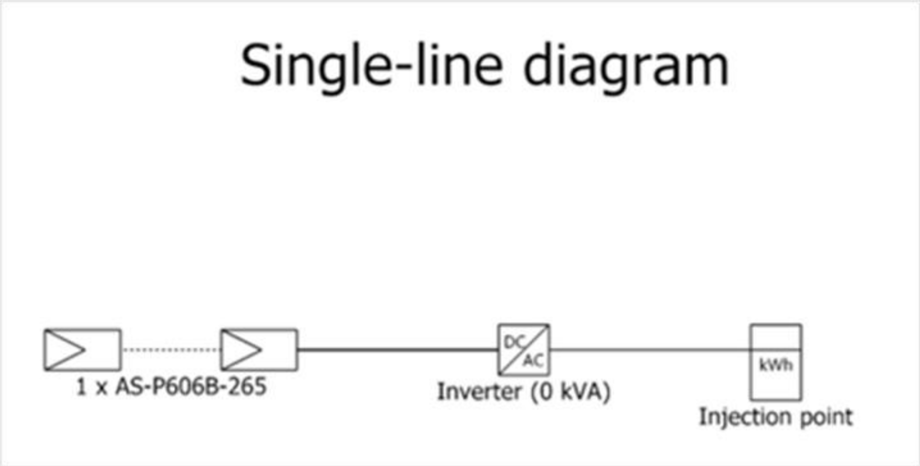


Figure 0.22 Single-line diagram:



Scenario 3:

In scenario number 3, we will simulate the critical factors, maintaining the default setting for operation throughout all seasons and days, coupled with an azimuth angle of 30 degrees. Additionally, we have encapsulated a summary of the outcomes from scenarios 1 and 2.

Table 16 summary of the outcomes from scenarios 1 and 2.

factors	Scenario 2	Scenario 1
latitude	57.02	57.09
longitude	9.98	9.98
Pv field orientation	FIXED	FIXED
Tilt/azimuth	45/0	30/0
Number of modules	1 UNIT	1 UNIT
Pnom total	265 W	240 W
Production energy	325.07 kwh /kwp/year	292.05 kwh /kwp/year
Specific production	1227 kwh/kwp/year	1102 kwh/kwp/year
Perf. ratio PR	88.89%	80.89%
NORMALIZED PROD	3.36 kwh/kwp/day	3.02kwh/kwp/day
ARRAY LOSSES	0.28 kwh/kwp/day	0.60 kwh/kwp/day
SYSTEM LOSSES	0.14 kwh/kwp/day	0.11 kwh/kwp/day

Table 17. Project Summary Scenario 3:

Situation:
Latitude: 57.09° N.
Longitude:9.85° E.
Altitude: 3 m.
Albedo: 0.20.
Meto data: metenorm 8.1 station -synthetic

Table 18. System Summary Scenario 3:

PV filed orientation: Fixed plane.
Tilt/Azimuth 40°/0.
Near shading: No shading.

Table 19. System Information Scenario 3:

PV ARRAY
Nb. of modules: 1 unit.
Pnom total: 265 Wp.
INVERTERS:
Nb. of units: 1 unit.
Pnom total: 240 W.
Pnom ratio: 1.104

Table 20. Result Summary Scenario 3:

Produced Energy: 309.56 KWH/YEAR.
Specific production: 1168 KWH/KWP/YEAR.
Perf. ratio PR: 89.60%

Site: Green hub house. AAU.
System Type: Grid-connected.
Simulation: 01/10 -12/31(Generic meteo data).

Table 21. PV array Scenario 3:

PV modules: AS-PS6068-265
MPP VOLTAGE: 31.1 V.
Nominal power: 0.27 KWP.
MPP current: 8.6 A.
Inventor: IQ7-60-x-INT (1panel input).
Inv. unit: 0.2 KW.
Nb. Of in 1.

Table 22. Main Result Scenario 3:

SYSTEM PRODUCTION: 310 KWH/YEAR.
SPECIFIC PROD.; 1168KWH/KWP/YEAR.
PERFORMANCE RATIO: 0.896.
NORMALIZED PROD: 3.20KWH/KWP/DAY.
ARRAY LOSSES: 0.26 KWH/KWP/DAY.
SYSTEM LOSSES: 0.11 KWH/KWP/DAY

Table 23. The balance and main result for scenario 3:

MONTH	GLOBHOR Kw/ m²	DIFFHOR KWh/ m²	T-AMB ^°C	GLOBLNC KWh/ m²	GLOBEFF KWh/ m²	E ARRAY kWh	G-GRID kWh	PR ratio
January	14	9.4	1.50	32	31.5	8.44	8.10	0.955
FEBRUARY	29.9	18.80	0.80	53.60	52.8	14.17	13.66	0.961
MARCH	81.9	38	3.10	126	123,7	32.23	31.21	0.935
APRIL	123.6	55.50	7.90	154.4	50.9	38.53	37.32	0.912
MAY	168.2	71.4	12	178.7	174.3	43.12	41.72	0.881
JUNE	178.6	78.30	15	179	174.4	42.83	41.45	0.874
JULY	170.3	79.50	18	173.9	169.3	41.09	39.73	0.862
August	134.5	69.80	17.70	150.6	146.8	35.85	34.67	0.868
September	83.8	40.30	13.50	118.7	116.2	28.95	27.98	0.890
October	46.5	26.30	8.90	78.8	77.5	19.89	19.21	0.919
November	16.8	11.20	5.40	35.2	34.7	9.15	8.76	0.939
December	8.8	6.4	1.90	22.8	22.4	6.06	5.76	0.954
YEAR	1056.9	504.90	8.86	1303.8	1274.5	320.32	309.56	0.898

Legends:

1. GlobHor: global horizontal irradiation.
2. DiffHor: horizontal diffuse irradiation.
3. T_Amb: Ambient Temperature.
4. GlobInc: Global incident in coll. plane.
5. GlobEff: Effective. Global, corr. for IAM and shading.
6. EArray: Effective energy at the output of the array.
7. E_Grid: Energy injected into the grid.
8. PR: PERFORMANCE Ratio.

Figure 0.23 Horizon profile for Scenario 3

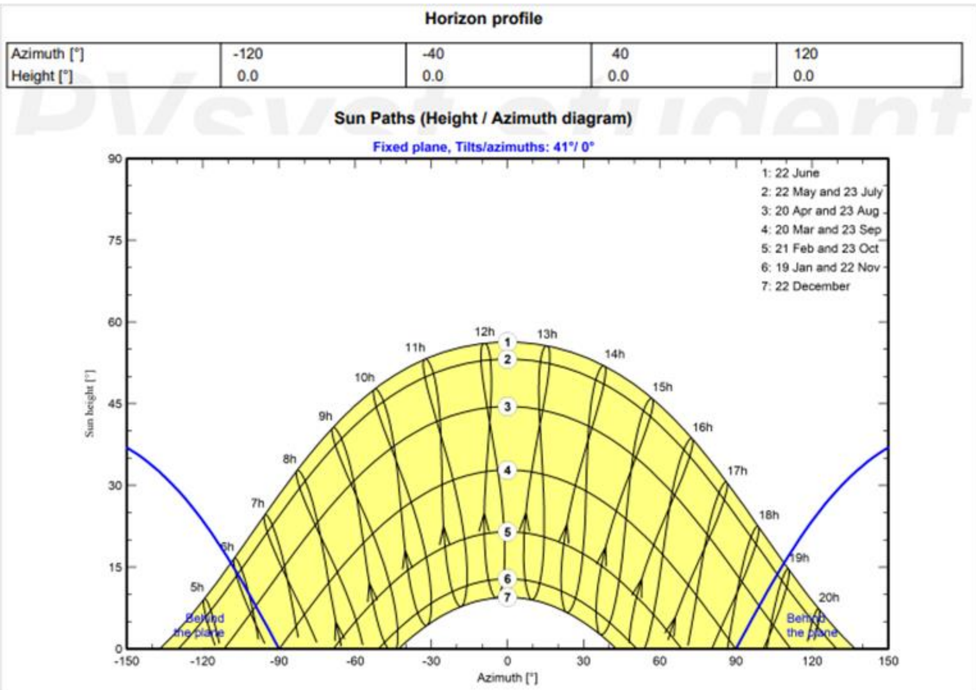
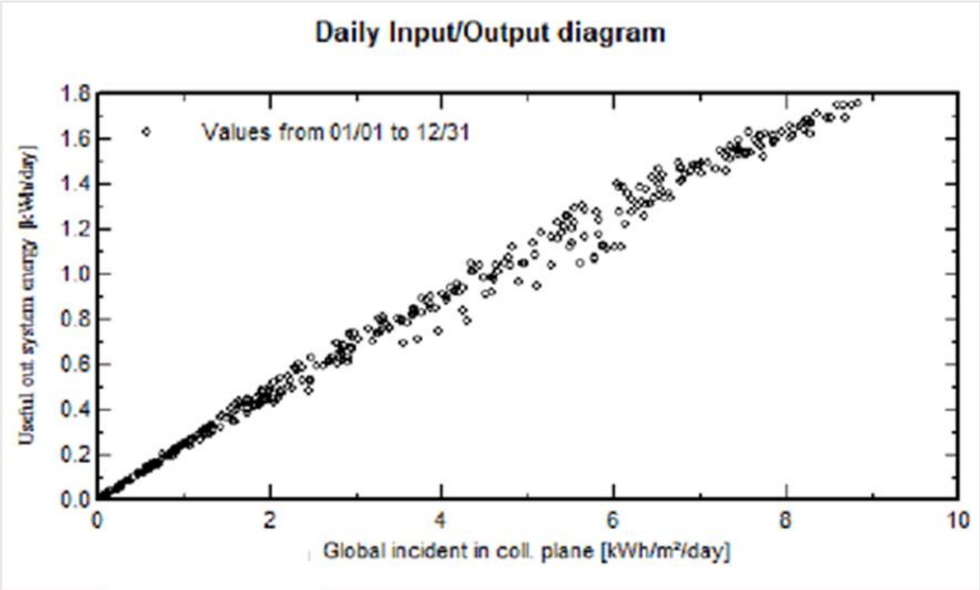
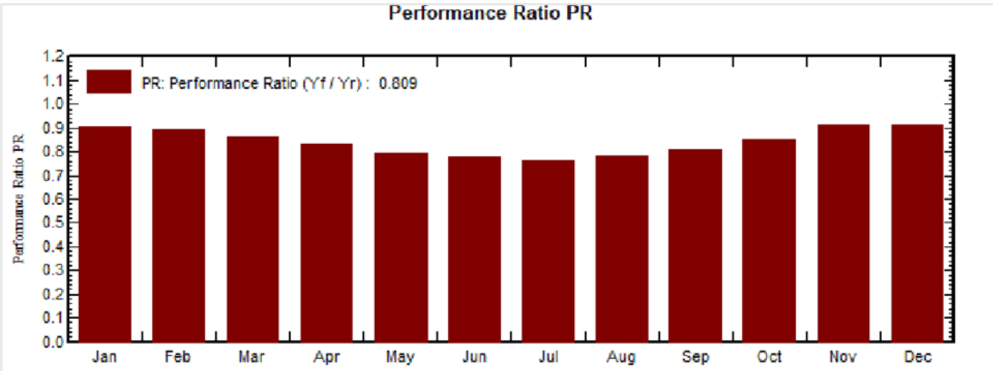


Figure 0.24 Daily Input/Output diagram



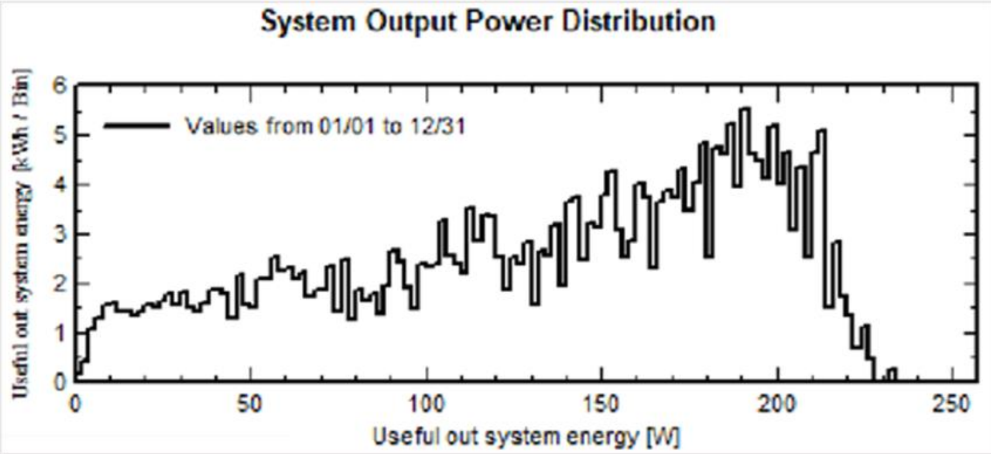
In this diagram, the received radiation density has a direct role with increasing output. For this geographical point, it is a function of increasing temperature and sunny days.

Figure 0.25 Performance ratio pr:



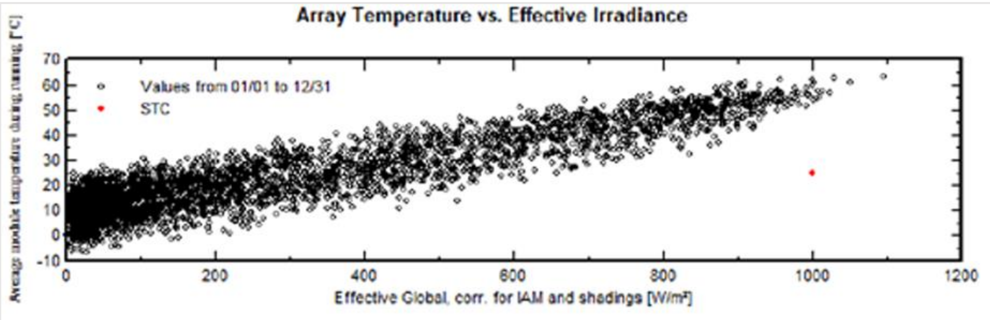
Performance ratio (PR), which is an important measure that affects the entire life cycle of a PV system, from design and implementation to continuous monitoring. PR ensures that the system is optimized for maximum performance under real-world conditions while considering various environmental variables that may affect its performance. According to the result, it can be said that this scenario based on simulation has a maximum yield of about 81 percent.

Figure 0.26 System Output Power Distribution



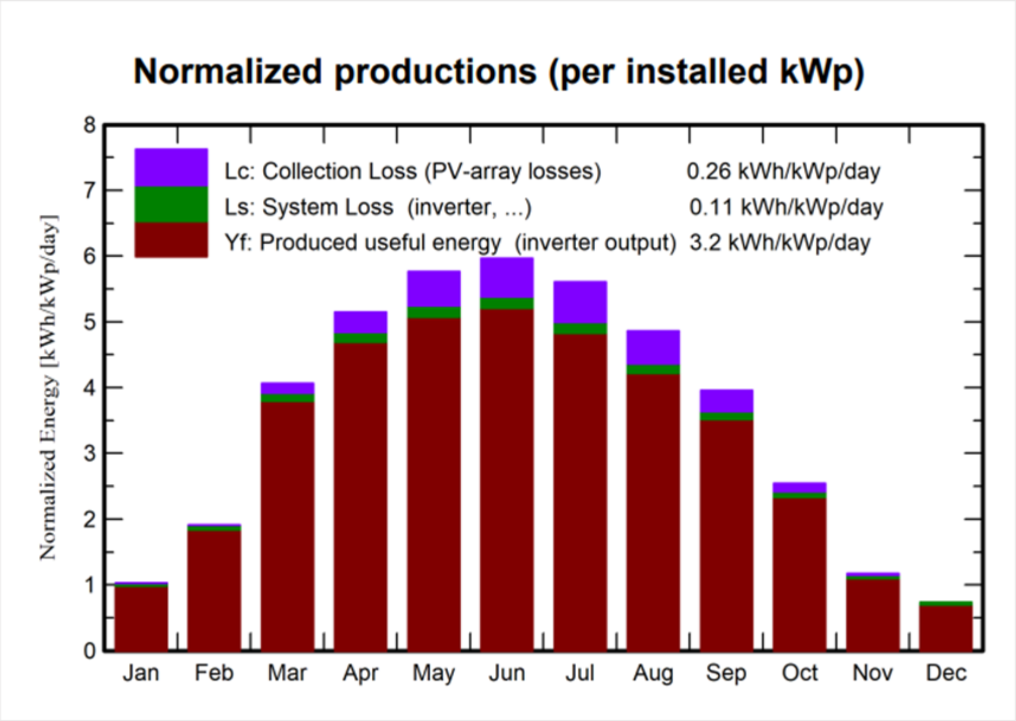
The diagram illustrates the direct impact of the solar system's efficiency on the energy output for the consumption of electrical devices and the energy stored in batteries. As depicted in the graph, higher levels of received radiation led to increased energy output for both network consumption and battery storage. This correlation highlights the crucial role of system efficiency in maximizing the utilization of solar energy, particularly on days with elevated radiation levels. (increase from day number60 to 210-but maximum days are:110-140-150-180-190-215)

Figure 0.27 Array Temperature vs. Effective Irradiance



The simulation proves this hypothesis that we face an increase in temperature on the surface of the cells with the increase in temperature and also receiving general radiation from all directions. The dispersion of this factor increases in the months leading to the summer season in Aalborg city and reaches a stability after passing this period.

Figure 0.28 Normalized production (per installed KWp)



In this scenario, the output energy from the inverter is measured at 3.2 kWh/Kwp/day. Additionally, the simulation indicates that approximately 0.26kWh/Kwp/day of energy is wasted in the cells, and about 0.11 kWh/Kwp/day is lost in the overall system. These values offer valuable data for fine-tuning the system, minimizing losses, and maximizing energy efficiency.

Figure 0.29 The loss diagram for scenario 3:

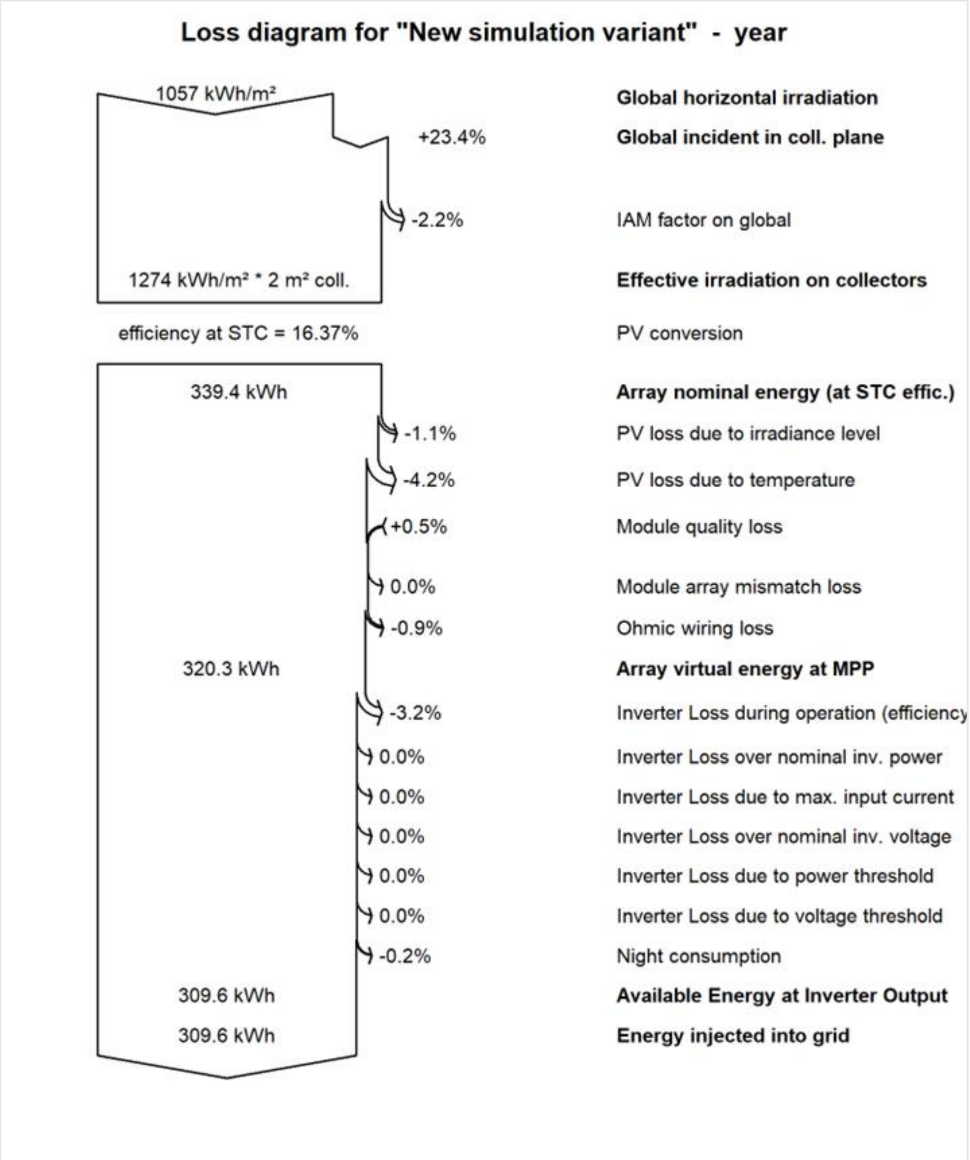


Figure 0.30 Single-line diagram:

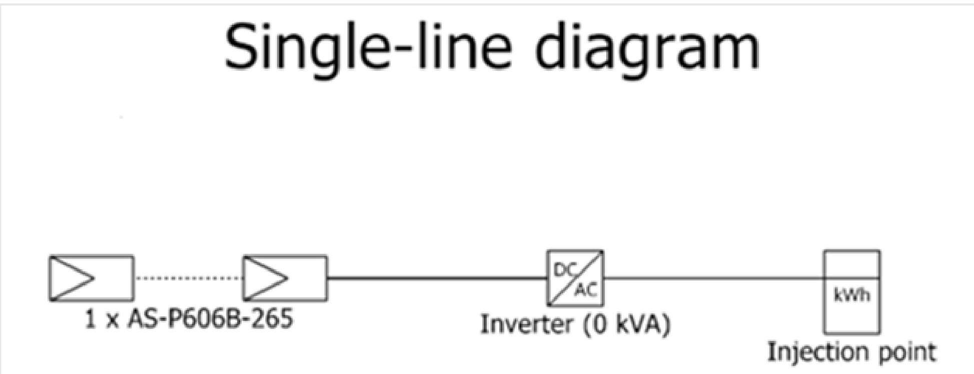
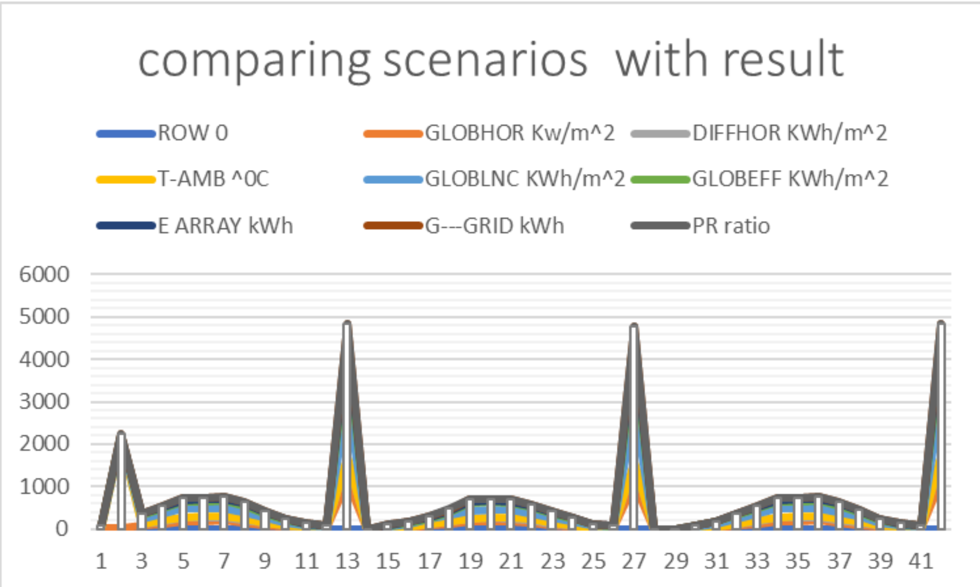


Table 24. Comparing systems1,2 and 3:

factors	Scenario 2	Scenario 3	Scenario 1
latitude	57.02	57.09	57.09
longitude	9.98	9.85	9.98
Pv field orientation	FIXED	FIXED	FIXED
Tilt/azimuth	45/0	40/0	30/0
Number of modules	1 UNIT	1 UNIT	1 UNIT
Pnom total	265 W	240 W	240 W
Production energy	325.07 kwh /kwp/year	309.56 kwh /kwp/year	292.05 kwh /kwp/year
Specific production	1227 kwh/kwp/year	1168 kwh/kwp/year	1102 kwh/kwp/year
Perf. ratio PR	88.89%	89.6%	80.89%
NORMALIZED PROD	3.36 kwh/kwp/day	3.20 kwh/kwp/day	3.02kwh/kwp/day
ARRAY LOSSES	0.28 kwh/kwp/day	0.26 kwh/kwp/day	0.60 kwh/kwp/day
SYSTEM LOSSES	0.14 kwh/kwp/day	0.11 kwh/kwp/day	0.11 kwh/kwp/day

Figure 0.31 comparing scenarios 1,2 and 3.



Conclusions for the first 3 examined scenarios:

Therefore, it can be concluded that installation at an angle of 45 degrees can have the highest amount of radiation absorption and energy production for the network. These calculations and simulations are without connecting any load to the network, and in the following scenarios, based on the amount of consumption, we will analyze the behavior of the network and the amount of production.

3.10.

Scenario 4 (based on 2023 data from NRGI company).

In scenarios 1, 2, and 3, we simulated the critical factors in solar cell design for a solar panel that spanned different azimuth angles. However, none of these scenarios included the definition of load as the load used to power the system. In the next section, we derive the consumption estimate based on the data of a distribution company in East Aalborg and simulate it as a basic element. As a result, in scenarios number 4 and 5, we will introduce the consumption of electricity by the consumer as a source in the simulation of our systems. This allows us to confirm a key goal in the Green Hub house project - specifically, the reduction of carbon dioxide production.

For scenario #4, we set the Tilt/azimuth to 45 degrees and intend to apply it to all seasons. The significant difference between scenarios 4 and 5 lies in the simulation approach, which involves connecting the consumer to the network. We started the simulation under so-called load conditions.

Table 25. situation of system scenario 4

Situation:
Latitude: 57.09° N.
Longitude:9.85° E.
Altitude: 3 m.
Albedo: 0.20.
Meto data: metenorm 8.1 station -synthetic

Table 26. PV filed. Scenario 4

PV filed orientation: Fixed plane.
Tilt/Azimuth 45°/0.
Near shading: No shading.

Table 27. System Information . Scenario 4:

PV ARRAY
Nb. of modules: 1 unit.
Pnom total: 290 Wp.
INVERTERS:
Nb. of units: 1 unit.
Pnom total: 290W.
Pnom ratio: 1.208

Table 28. Result Summary . Scenario 4:

Produced Energy: 333.87 KWH/YEAR.
Specific production: 1151 KWH/KWP/YEAR.
Perf. ratio PR: 88.41%

Site: Green hub house. AAU.
System Type: Grid-connected.
Simulation: 01/10 -12/31(Generic meteo data).

Table 29. PV array Scenario 4:

PV modules: P290 Wp 60 cells
MPP VOLTAGE: 30 V.
Nominal power: 0.290 KWP.
MPP current: 8.8 A.
Inventor: IQ7-60-x-INT (1panel input).
Inv. unit: 0.2 KW.
Nb. Of in 1.

Table 30. Main Result . Scenario 4:

SYSTEM PRODUCTION: 333.45 KWH/YEAR.
SPECIFIC PROD.; 1150KWH/KWP/YEAR.
PERFORMANCE RATIO: 0.883.
NORMALIZED PROD: 3.19KWH/KWP/DAY.
ARRAY LOSSES: 0.26 KWH/KWP/DAY.
SYSTEM LOSSES: 0.11 KWH/KWP/DAY

Table 31. The balance and main result for scenario 4:

MONTH	GLOBHOR Kw/ m²	DIFFHOR KWh/ m²	T-AMB ^°C	GLOBLNC KWh/ m²	GLOBEFF KWh/ m²	E ARRAY kWh	G-GRID kWh	EFrGrid kWh
January	14	9.4	1.50	33.2	32.8	9.54	0	176.5
FEBRUARY	29.9	18.80	0.80	54.9	54.2	15.82	0	154.6
MARCH	81.9	38	3.10	127.7	125.5	35.68	0	153.8
APRIL	123.6	55.50	7.90	154.2	150.8	42.09	0	141.9
MAY	168.2	71.4	12	176.2	171.9	46.56	0	144.1
JUNE	178.6	78.30	15	175.6	171	46.03	0	138.5
JULY	170.3	79.50	18	170.9	166.4	44.24	0	146.1
August	134.5	69.80	17.70	149.2	145.5	38.90	0	150.9
September	83.8	40.30	13.50	119.7	117.2	31.92	0	151.5
October	46.5	26.30	8.90	80.5	79.2	22.18	0	166.7
November	16.8	11.20	5.40	36.3	35.9	10.30	0	172.1
December	8.8	6.4	1.90	23.7	23.4	6.87	0	181.4
YEAR	1056.9	504.90	8.86	1302.3	1273.7	350.11	0	1878

Legends:

1. GlobHor: global horizontal irradiation.
2. DiffHor: horizontal diffuse irradiation.
3. T_Amb: Ambient Temperature.
4. GlobInc: Global incident in coll. plane.
5. GlobEff: Effective. Global, corr. for IAM and shading.
6. EArray: Effective energy at the output of the array.
7. EFrGrid: Energy from the grid.
8. PR: PERFORMANCE Ratio.

3.11. IAM LOSS FACTOR

Why do we need to know the IAM factor?

Understanding table 32:

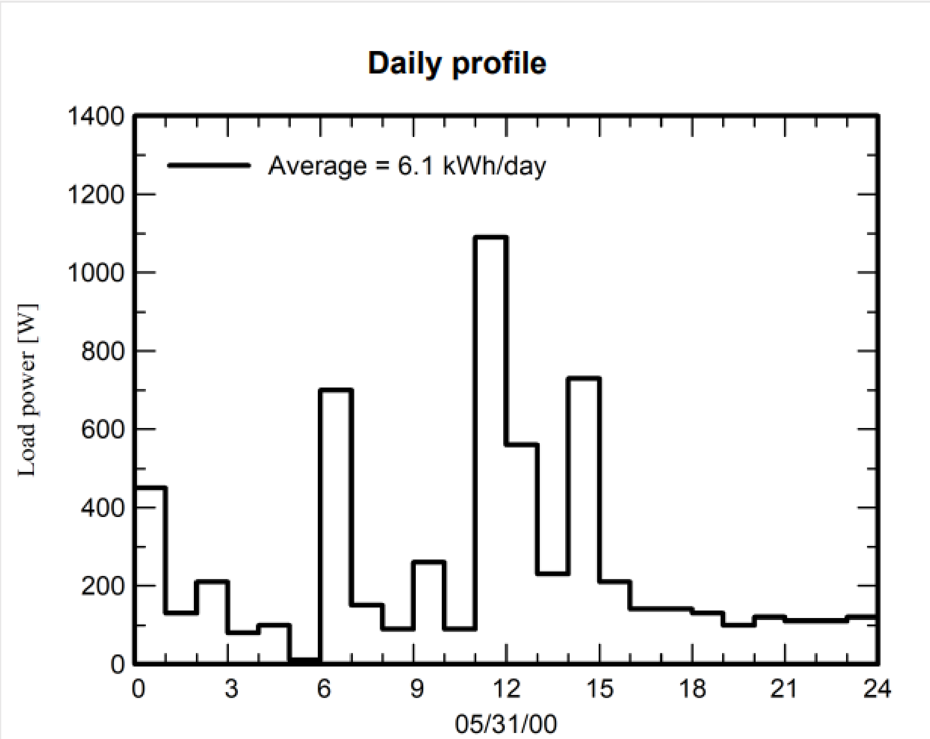
The incident angle modifier loss factor (IAM) is a factor that shows how sunlight can affect the efficiency of our solar cells. When the sunlight shines perpendicularly and at 90 degrees to the cells, the most suitable position for the cells is from the idea is to receive the most sunlight to be more efficient. By increasing or decreasing the radiation angle from this optimal position, the amount of sunlight absorption and its conversion into electricity decreases. Therefore, by knowing this factor, one can decide on the definition of inclination angle and azimuth, which has a direct effect on the amount of sunlight received. and as a result, increase or decrease the output from the system. On the other hand, by knowing this factor, it is possible to check the increase in temperature in the cells themselves and compare different scenarios. In table32, we have examined this factor from several angles. Therefore, examining this factor has a direct impact on the design of our solar cell system and provides us with the appropriate configuration to have the highest possible power.

Incidence effect (IAM): Fresnel, AR coating, n(glass)=1.526, n(AR)=1.290

Table 32. IAM LOSS FACTOR

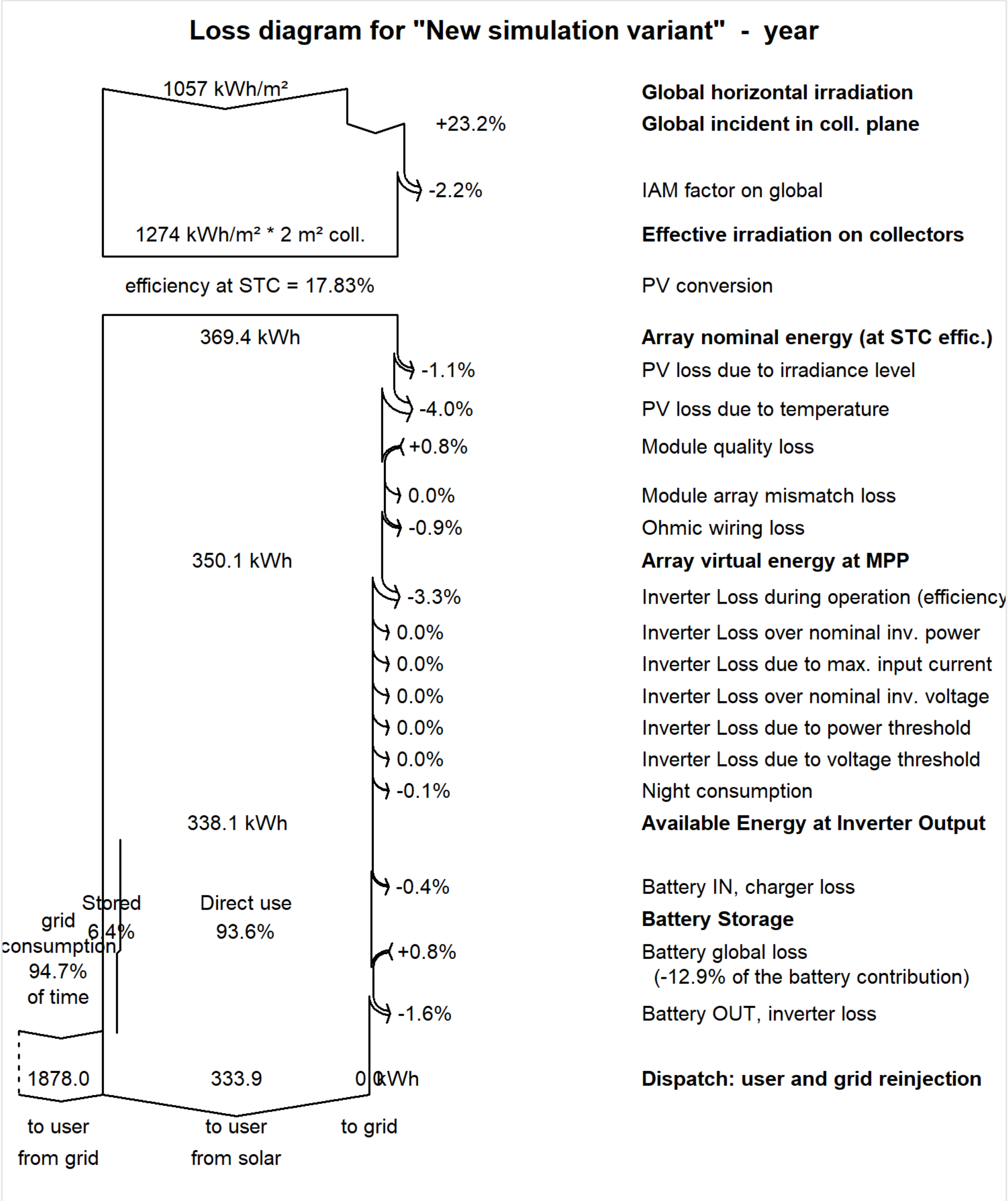
0°	30°	50°	60°	70°	75°	80°	85°	90°
1	0.999	0.987	0.962	0.892	0.816	0.681	0.440	0

Figure 0.32 daily profile



According to this diagram, there are consumption peaks at 1 am, 6 am, 11 am, and 14 and 15, and the highest consumption was at 11 am.

Figure 0.33 loss diagram. 2023



3.12. The term reference accident energy on the collector plate:

The phrase "Reference Lower Energy" is a commonly used term in the solar energy and photovoltaic systems industry. It is used to describe the amount of solar energy that a collector plate or surface is exposed to under specific conditions. This term serves as a performance benchmark for solar panels and is expressed in solar radiation power per unit area. It denotes the amount of solar light exposure that the solar collector experiences under standard conditions, which may include factors such as the angle of the sun, atmospheric conditions, orientation and tilt angle of the collector's plate, and temperature. Standardizing the reference energy value allows solar engineers and researchers to compare the actual energy output of a solar collector with the expected or standardized performance. This helps to evaluate the efficiency and effectiveness of solar panels or other solar energy systems under different environmental conditions and optimize their design and placement to maximize energy absorption.

What is the purpose of figure 3.34?

Understanding figure 3.34:

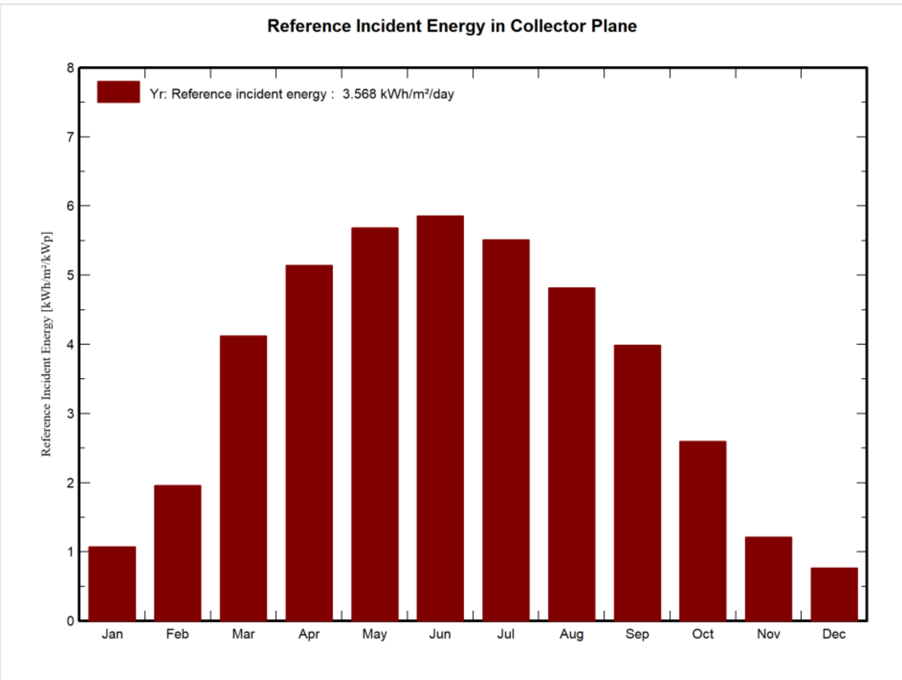
In the context of my PV system project, the term "incident energy at the collector plate" is a critical parameter influencing both the overall design and safety considerations. This term specifically denotes the amount of energy that the solar collector plate may encounter under unforeseen or random conditions. Understanding and simulating this factor are pivotal in ensuring the selection of the most suitable panel type for our project.

The simulation of incident energy takes into consideration unpredictable circumstances, including sudden load surges in the network caused by variations in voltage, frequency, or reactive load. By assessing how much energy the solar panel can withstand under these conditions, we account for physical shocks or abrupt changes in the power system environment. This knowledge becomes particularly significant as it directly impacts the robustness and resilience of our chosen panel type.

During the PV system design phase, a thorough understanding of the potential incident energy on the collector plate becomes indispensable for guaranteeing the safety and reliability of the overall system. This understanding plays a key role in determining the structural strength of the collector plate and aids in the selection of materials that can effectively endure unexpected events such as extreme weather conditions, impacts, or other unforeseen incidents.

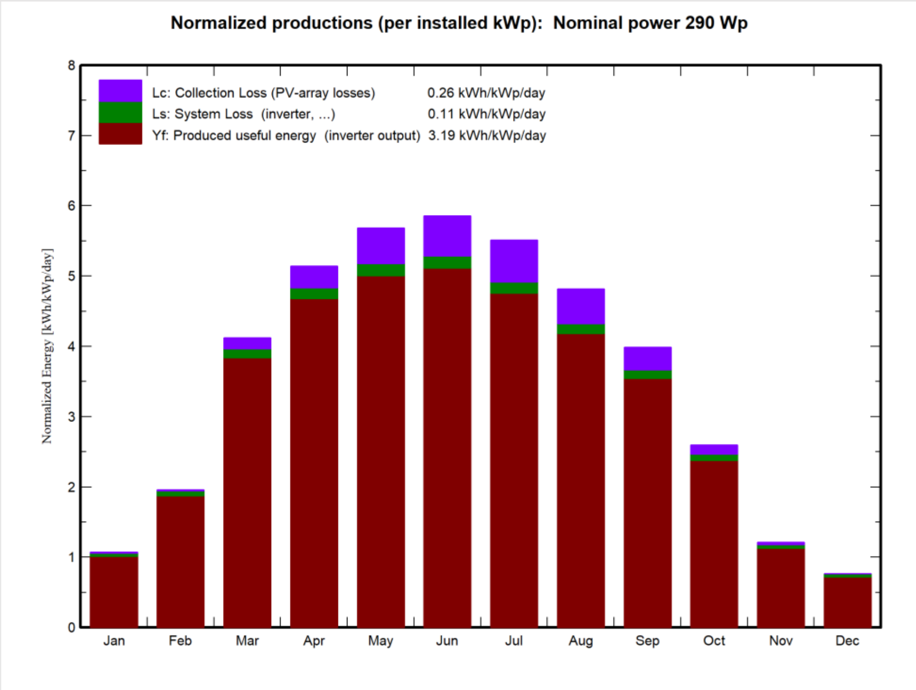
In essence, recognizing and incorporating the impact of incident energy on the collector plate is a proactive approach in our design process. It enables us to tailor the system to withstand unforeseen challenges, contributing to the overall safety and longevity of the PV system in various operating conditions.

Figure 0.34 reference incident energy in collector plane.2023



Based on the simulation of incident energy at the collector plate, the annual average amount was approximately 3.56 KWH/M^2/DAY. The lowest recorded rate occurred in December at around 0.9 KWH/M^2/DAY, while the highest was observed in the month of Jun, reaching approximately 5.80 KWH/M^2/DAY.

Figure 0.35 normalized production .2023



According to the simulated diagram, the inverter exhibited the highest output in the month of Zone, reaching 5 kWh/Wp/day, while the lowest output was recorded in December at 0.8 kWh/Wp/day. The average daily production amounted to 3.19 kWh/Wp/day. It's noteworthy that the highest losses in arrays and inverters occurred in the month of Zone, whereas the lowest losses were observed in December. This observation suggests that an increase in production is associated with a corresponding increase in losses in both the inverter and cells.

Figure 0.36 normalized production and loss factor. 2023

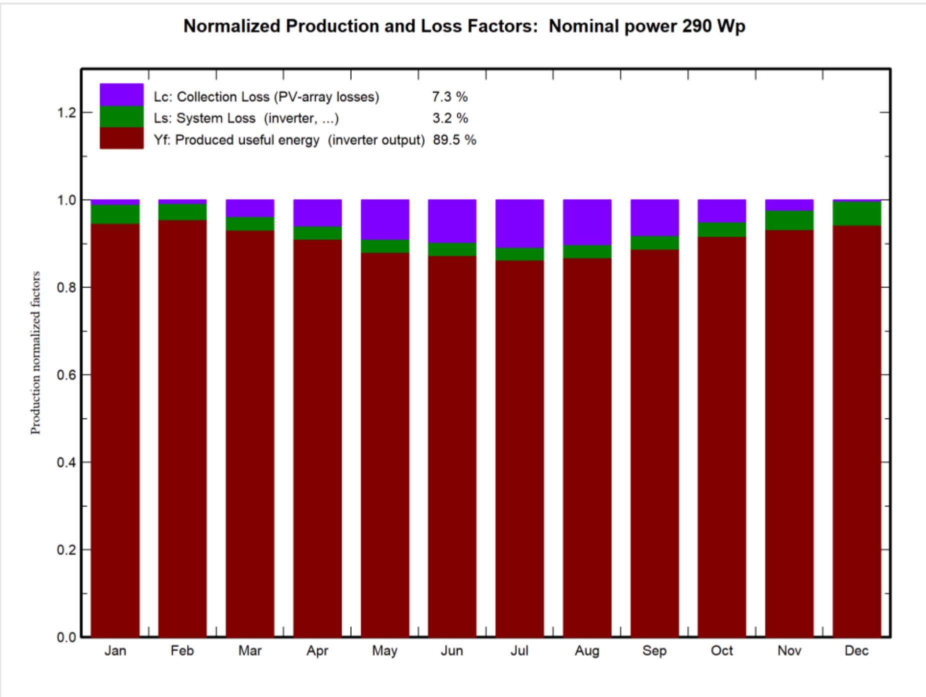
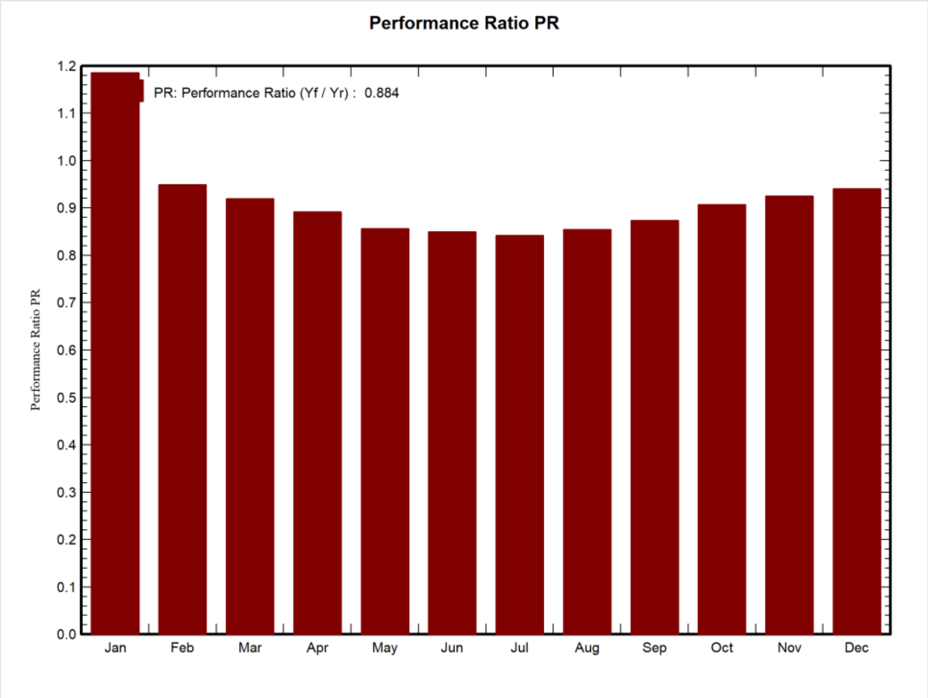


Figure 0.37 performance ratio PR. 2023



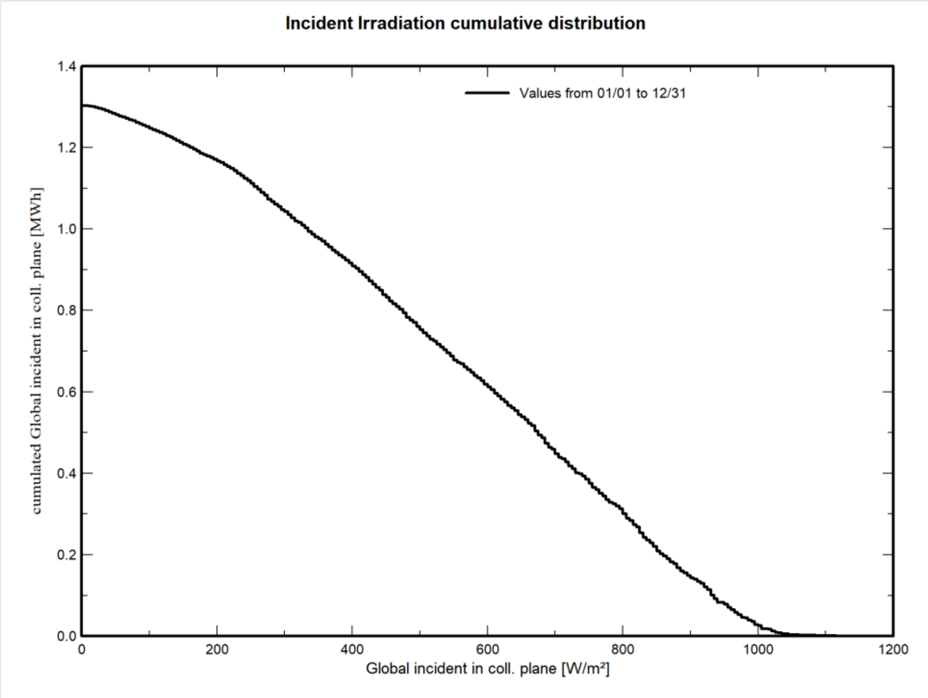
According to the simulated graph, the average performance of the system throughout the year is approximately 0.88. The highest efficiency occurs in January, reaching about 1.2, while the lowest efficiency is around 0.83 in the month of July. These values reflect the system's performance and efficiency under the influence of various factors and favorable conditions for production.

3.13. The cumulative distribution of the collision:

The cumulative distribution of collisions on the collector plate serves as a representation of the probability or likelihood of various collision events. This factor plays a pivotal role in simulating areas where incidents and load accumulation may potentially occur. The optimization of this factor is key to arranging the collector plate efficiently, and through simulation, it allows for the optimization of received light.

Essentially, this factor ensures that the load is evenly distributed across the array, preventing certain areas from being shaded or experiencing temperature increases that could lead to incidents. The optimization process involves strategic placement and configuration adjustments to enhance the overall efficiency and safety of the collector plate.

Figure 0.38 incident Irradiation cumulative distribution. 2023



This simulation proves the hypothesis that as the total amount of radiation increases in all directions, the same amount of output is increasing in any period. It is the highest amount of total radiation.

3.14 The daily output energy of a photovoltaic system (PV):

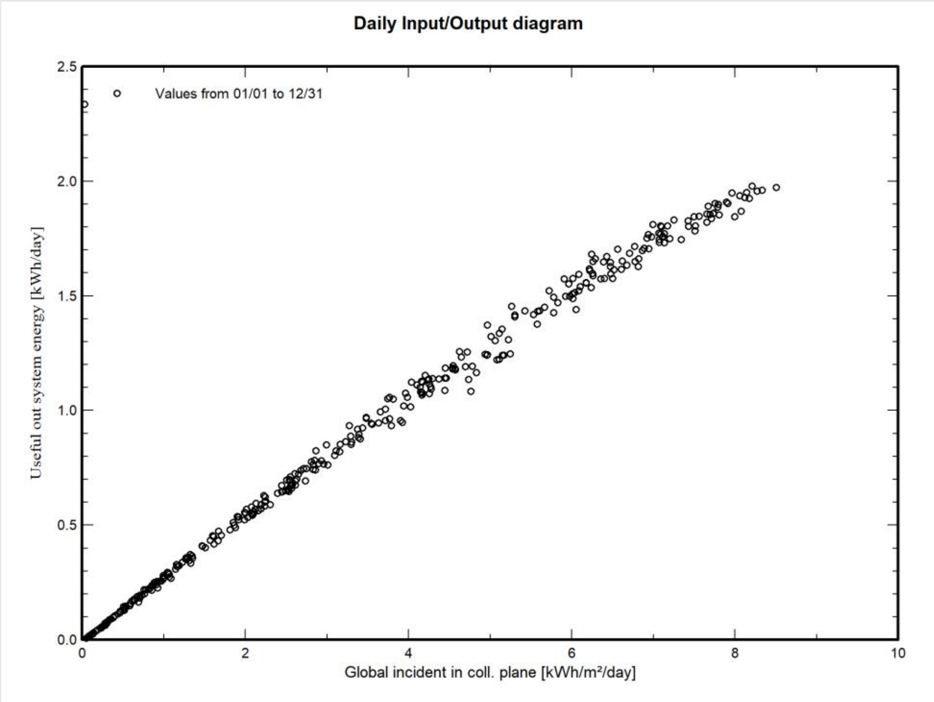
Here we explain its importance in our project:

System size: The daily energy output figure helps determine the size of the PV system needed to supply us with the energy we need. By analyzing the amount of energy, the system can produce daily, we can seize the system according to our daily consumption needs.

Knowing this factor, we can use it to change the azimuth or change the angle of inclination to increase productivity. Therefore, by increasing the output and knowing this important factor, we can define the number of batteries and the amount of battery capacity in terms of hours. The size of the batteries and how they are arranged will also be affected by this factor. On the other hand, the way we interact with the national electricity grid, as well as determining the strategy of defining the use and efficiency of batteries, is effective in determining when to deliver or receive loads to the grid.

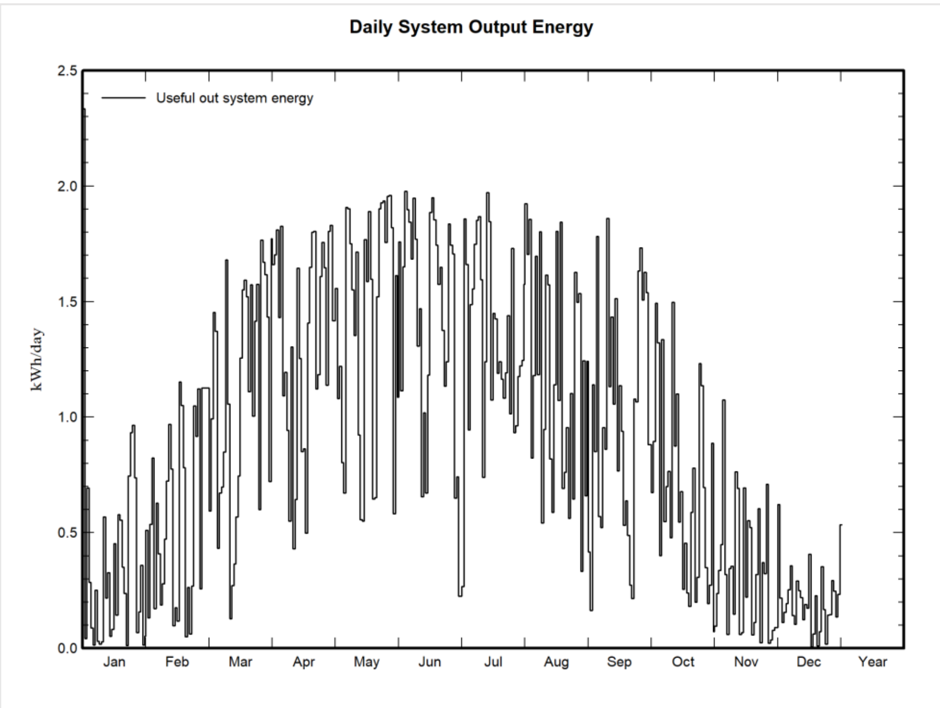
Economic considerations: The figure of daily energy production is part of economic considerations. This affects the return on investment (ROI) calculations, the payback period, and the overall cost-effectiveness of the PV system. This allows you to assess the financial viability of your project.

Figure 0.39 daily input /output diagram. 2023



This simulated graph illustrates the daily production and system output, which increases progressively from the beginning of the year, reflecting the transition from colder to warmer seasons. It's important to note that "all the received light" refers to the total incident radiation on the panels, encompassing radiation received at a 90-degree angle and from all directions around the cell.

Figure 0.40 daily system output energy. 2023



According to this simulated diagram, the system output experiences an increase in March, maintaining a favorable level with some fluctuations until the middle of October. Subsequently, the daily output gradually declines, reaching its lowest point in the middle and late days of December.

3.15 Array power distribution:

refers to how electrical power is managed within a photovoltaic (PV) solar panel array or solar farm. In a solar panel array, multiple individual solar panels are interconnected to generate electricity. Efficient power distribution within the array is essential for optimizing energy production and ensuring that all panels perform at their best.

3.16 Key aspects of array power distribution include:

Series and Parallel Connections: Solar panels in an array are typically connected in series and parallel configurations. In a series connection, panels are linked end-to-end, which increases the voltage output. In a parallel connection, panels are connected side-by-side, increasing the current output. The combination of series and parallel connections determines the array's overall electrical characteristics.

Inverters: Most PV arrays incorporate inverters that convert the direct current (DC) electricity generated by the panels into alternating current (AC) electricity, suitable for use in homes and businesses. Inverters also play a crucial role in power distribution, managing the flow of electricity from the array to the electrical grid or on-site loads.

3.17 Maximum Power Point Tracking (MPPT):

Some PV systems utilize MPPT technology to optimize the power output of individual panels by adjusting voltage and current based on changing environmental conditions. MPPT controllers ensure that each panel operates at its maximum power point, enhancing energy production efficiency.

3.18 Monitoring and Control:

Modern PV systems are equipped with monitoring and control systems that enable operators to track the performance of individual panels or groups of panels within the array. This information helps identify issues such as shading, dust accumulation, or malfunctioning panels, facilitating timely maintenance.

3.19 Cabling and Wiring:

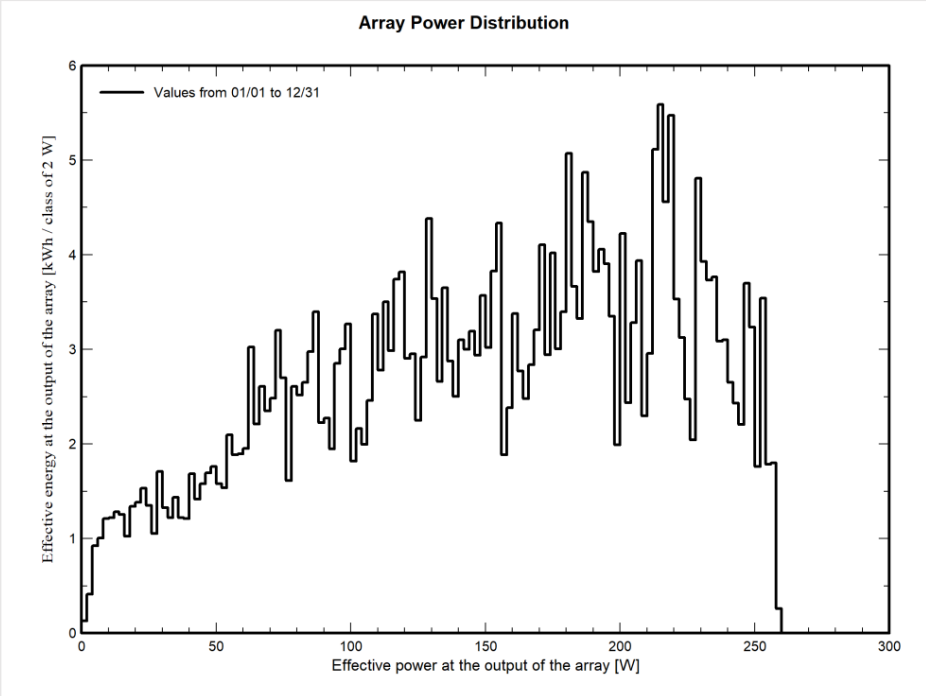
Proper wiring and cabling are critical for safe and efficient power distribution within the array. This includes selecting appropriate wire sizes and ensuring secure connections to minimize power losses.

3.20 Voltage and Current Distribution:

Maintaining balanced voltage and current distribution within the array is essential to ensure that no single panel is overloaded or underutilized. Balanced distribution contributes to the overall performance and longevity of the PV system.

Effective array power distribution is crucial for optimizing energy output from a solar panel array, ensuring the durability of the panels, and maximizing the return on investment for solar energy systems. Engineers and installers carefully plan and design the power distribution system to meet the specific requirements of the installation and achieve desired performance goals.

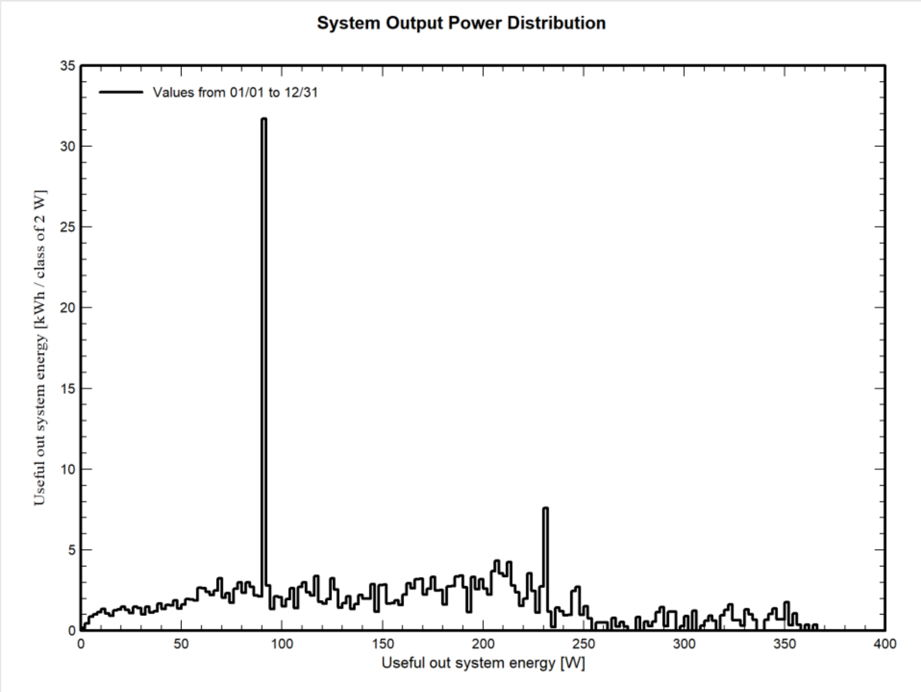
Figure 0.41 array power distribution. 2023



This graph illustrates the correlation between the effective power output from the arrays, measured in watts at specific moments, throughout the entire year. The corresponding data is then compared to the cumulative effective energy output in the system, measured in kilowatt-hours. Based on the previously provided diagram and explanations, considering influential environmental factors and the role of control equipment, it can be inferred that as temperature rises and solar panel radiation increases, the effective power output from the arrays demonstrates a proportional increase, resulting in a corresponding rise in the overall energy output from the entire system. This relationship is direct and indicates a positive correlation between environmental conditions, array power output, and system energy generation. This increase continues from day 60 to 230 and has the highest output on day 210.

Effective Energy (kWh)=Effective Power (kW)×Time (hours)

Figure 0.42 system output power distribution. 2023



The diagram illustrates the direct impact of the solar system's efficiency on the energy output for the consumption of electrical devices and the energy stored in batteries. As depicted in the graph, higher levels of received radiation led to increased energy output for both network consumption and battery storage. This correlation highlights the crucial role of system efficiency in maximizing the utilization of solar energy, particularly on days with elevated radiation levels. (increase from day number 90 to 230-but maximum days are:90-120-150-230)

3.21 The system output power cumulative distribution:

often referred to as the cumulative distribution function (CDF) of system output power, is a statistical representation of the distribution of electrical power output from a specific system or set of systems over a given period. This distribution is used to understand how frequently the system produces different levels of electrical power.

Here's how it works:

Data Collection: To create a system output power cumulative distribution, you collect data on the electrical power output of the system(s) at regular intervals over a specific period. For example, you might measure the power output every minute, every hour, or daily, depending on your analysis needs.

Data Analysis: After collecting the data, you sort the power output values in ascending order, from the lowest to the highest.

Cumulative Probability: For each power output value, you calculate the cumulative probability, which represents the probability that the power output will be less than or equal to that specific value. This probability is calculated as the number of observations (power output values) less than or equal to the value in question divided by the total number of observations.

Cumulative Distribution Function (CDF):

The cumulative probability values are plotted against their corresponding power output values, creating a cumulative distribution function (CDF) curve. This curve provides insights into the system's performance by showing how often the system operates at different power levels.

Interpretation:

By analyzing the CDF curve, you can understand various aspects of the system's behavior. For example, you can determine the probability of the system producing a certain minimum or maximum power output, identify the median (50th percentile) power output, or assess the variability in power production.

The system output power cumulative distribution is particularly useful in fields like renewable energy, where power generation can be variable due to factors like weather conditions. It helps in assessing the reliability and performance of a power generation system, estimating energy production for planning purposes, and understanding the range of power output scenarios that the system may encounter.

In summary, the system output power cumulative distribution is a statistical tool used to analyze and visualize the distribution of electrical power output from a system, providing valuable insights into its performance and behavior.

Understanding figure 3.43:

Understanding system performance:

The cumulative distribution of system output power provides insights into the overall performance of the PV system over a given period.

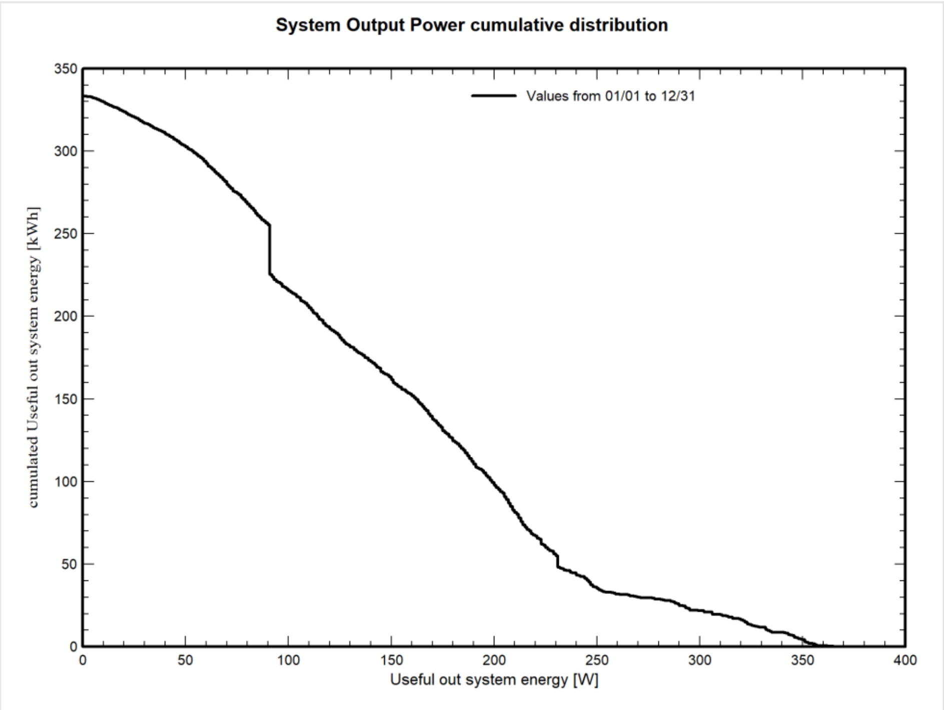
By considering changes in sunlight, weather, and other environmental factors, it helps to identify the power output range under different conditions.

Optimization of size and capacity:

By analyzing the cumulative distribution, you can determine the frequency and duration of different power output levels.

This information is critical to properly sizing the PV system to meet energy needs, considering average and peak power generation.

Figure 0.43 system output power cumulative distribution. 2023



Co2 emission:

Table 33. Co2 details

SYSTEM LIFECYCLE EMISSIONS DETAILS			
Item	**LCE**	**QUANTITY**	**SUBTOTAL**
			(kgco2)
modules	**1713kgCO2/Kwp**	**0.29kWp**	**497**
supports	**2.57kgCO2/kg**	**10.00kg**	**25.7**
inverters	**254kgCO2/units**	**1.00unit**	**254**

Scenario 5(based on data for 2022 from NRGI company):

In scenario number 5, we focus on a consumer located in the eastern part of Aalborg city, analyzing their consumption data for April. The objective is to simulate the production output from a solar cell connected to this load. This simulation aims to explore critical factors influencing the design, selection, and configuration of solar cell arrays. It is grounded in the real consumption data of an individual consumer, encompassing aspects such as production capacity, conversion efficiency, and storage considerations. Additionally, the simulation evaluates the carbon dioxide mitigation potential.

Specifically, in this scenario, we have set the Tilt/azimuth at 45 degrees. The choice of this azimuth angle is deliberate, and we intend to conduct a comparative analysis. By simulating the annual production based on this specific azimuth angle, we seek to juxtapose and evaluate it against the actual consumption patterns observed throughout the year.

In summary, scenario 5 delves into a real-world scenario, using actual consumption data to drive the simulation of solar cell production. The emphasis on Tilt/azimuth at 40 degrees allows for a comprehensive analysis of the solar cell array's effectiveness over an entire year, providing valuable insights into the optimal design and configuration for enhanced energy generation and carbon footprint reduction.

Table 34. situation of system. April 2022)

Situation:
Latitude: 57.09° N.
Longitude:9.85° E.
Altitude: 3 m.
Albedo: 0.20.
Meto data: metenorm 8.1 station -synthetic

Table 35. System Summary scenario 5:

PV filed orientation: Fixed plane.
Tilt/Azimuth 40°/0.
Near shading: No shading.

Table 36. System Information scenario 5:

PV ARRAY
Nb. of modules: 1 unit.
Pnom total: 290 Wp.
INVERTERS:
Nb. of units: 1 unit.
Pnom total: 290W.
Pnom ratio: 1.104

Table 37. Result Summary scenario 5:

Produced Energy: 333.45 KWH/YEAR.
Specific production: 1150 KWH/KWP/YEAR.
Perf. ratio PR: 88.30%

Site: Green hub house. AAU.
System Type: Grid-connected.
Simulation: 01/10 -12/31(Generic meteo data).

Table 38. PV array scenario 5:

PV modules: P290 Wp 60 cells
MPP VOLTAGE: 30 V.
Nominal power: 0.27 KWP.
MPP current: 8.8 A.
Inventor: IQ7-60-x-INT (1panel input).
Inv. unit: 0.2 KW.
Nb. Of in 1.

Table 39. Main Result scenario 5:

SYSTEM PRODUCTION: 333.45 KWH/YEAR.
SPECIFIC PROD.; 1150KWH/KWP/YEAR.
PERFORMANCE RATIO: 0.883.
NORMALIZED PROD: 3.19KWH/KWP/DAY.
ARRAY LOSSES: 0.26 KWH/KWP/DAY.
SYSTEM LOSSES: 0.11 KWH/KWP/DAY

Table 40. The balance and main result for scenario 5:

MONTH	GLOBHOR Kw/ m²	DIFFHOR KWh/ m²	T-AMB ^°C	GLOBLNC KWh/ m²	GLOBEFF KWh/ m²	E ARRAY kWh	G-GRID kWh	EFrGrid kWh
January	14	9.4	1.50	33.2	32.8	9.54	0	127.8
February	29.9	18.80	0.80	54.9	54.2	15.82	0	123.9
March	81.9	38	3.10	127.7	125.5	35.68	0	121.6
April	123.6	55.50	7.90	154.2	150.8	42.09	0	111.1
May	168.2	71.4	12	176.2	171.9	46.56	0	112.0
June	178.6	78.30	15	175.6	171	46.03	0	107.3
July	170.3	79.50	18	170.9	166.4	44.24	0	113.2
August	134.5	69.80	17.70	149.2	145.5	38.90	0	117.9
September	83.8	40.30	13.50	119.7	117.2	31.92	0	119.6
October	46.5	26.30	8.90	80.5	79.2	22.18	0	133.2
November	16.8	11.20	5.40	36.3	35.9	10.30	0	138.8
December	8.8	6.4	1.90	23.7	23.4	6.87	0	147
YEAR	1056.9	504.90	8.86	1302.3	1273.7	350.11	0	1473.3

Legends:

1. GlobHor: global horizontal irradiation.
2. DiffHor: horizontal diffuse irradiation.
3. T_Amb: Ambient Temperature.
4. GlobInc: Global incident in coll. plane.
5. GlobEff: Effective. Global, corr. for IAM and shading.
6. EArray: Effective energy at the output of the array.
7. EFrGrid: Energy from the grid.
8. PR: PERFORMANCE Ratio.

3.22 IAM LOSS FACTOR

Incidence effect (IAM): Fresnel, AR coating, n(glass)=1.526, n(AR)=1.290

Figure 0.44 IAM LOSS FACTOR scenario 5:

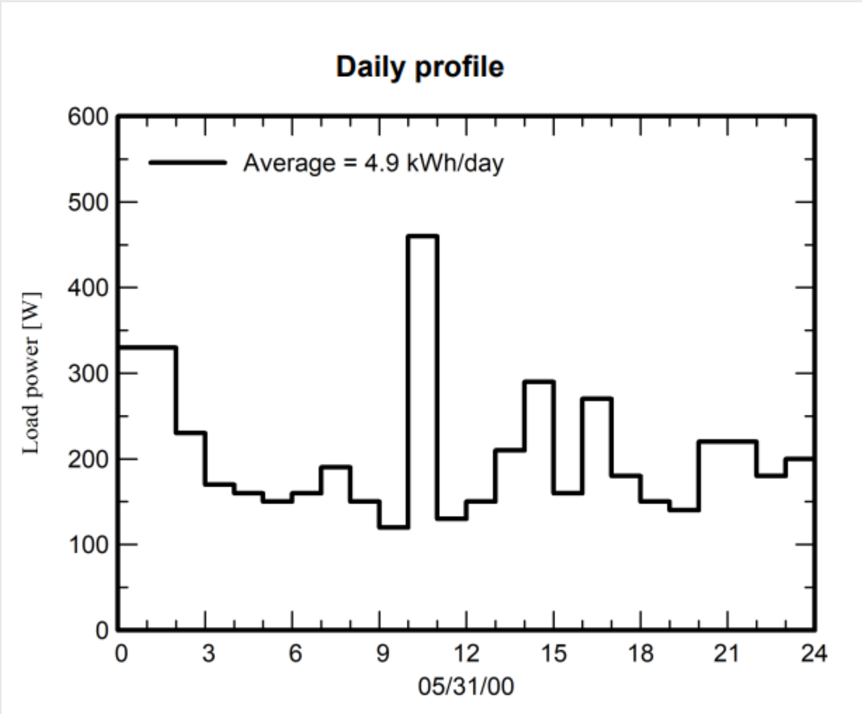
0°	30°	50°	60°	70°	75°	80°	85°	90°
1	0.999	0.987	0.962	0.892	0.816	0.681	0.440	0

Daily profile, constant over the year, average 4.9kwh/day.

Table 41. Daily Profile

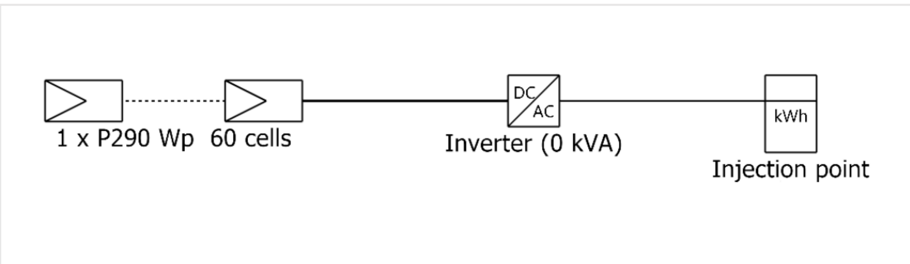
HOURLY LOAD	0H 0.33	1H 0.33	2H 0.23	3H 0.17	4H 0.16	5H 0.15	6H 0.16	7H 0.19	8H 0.15	9H 0.12	10H 0.46	11h 0.13
	12H 0.15	13H 0.21	14H 0.29	15H 0.16	16H 0.27	17H 0.18	18H 0.15	19H 0.14	20H 0.22	21H 022	22H 0.18	23H 0. 2

Figure 0.45 Daily profile. April 2022



According to this diagram, there are consumption peaks at 1 am, 7 am, 11 am, and 14 and 16, and the highest consumption was at 14 pm.

Figure 0.45 Single line diagram:



Co2 emission:

Table 42 Co2 details. 2022

SYSTEM LIFECYCLE EMISSIONS DETAILS			
item	**LCE**	**QUANTITY**	**SUBTOTAL**
			(kgco2)
modules	**1713kgCO2/Kwp**	**0.29kWp**	**497**
supports	**2.57kgCO2/kg**	**10.00kg**	**25.7**
inverters	**254kgCO2/units**	**1.00unit**	**254**

Figure 0.46 loss diagram 2023.

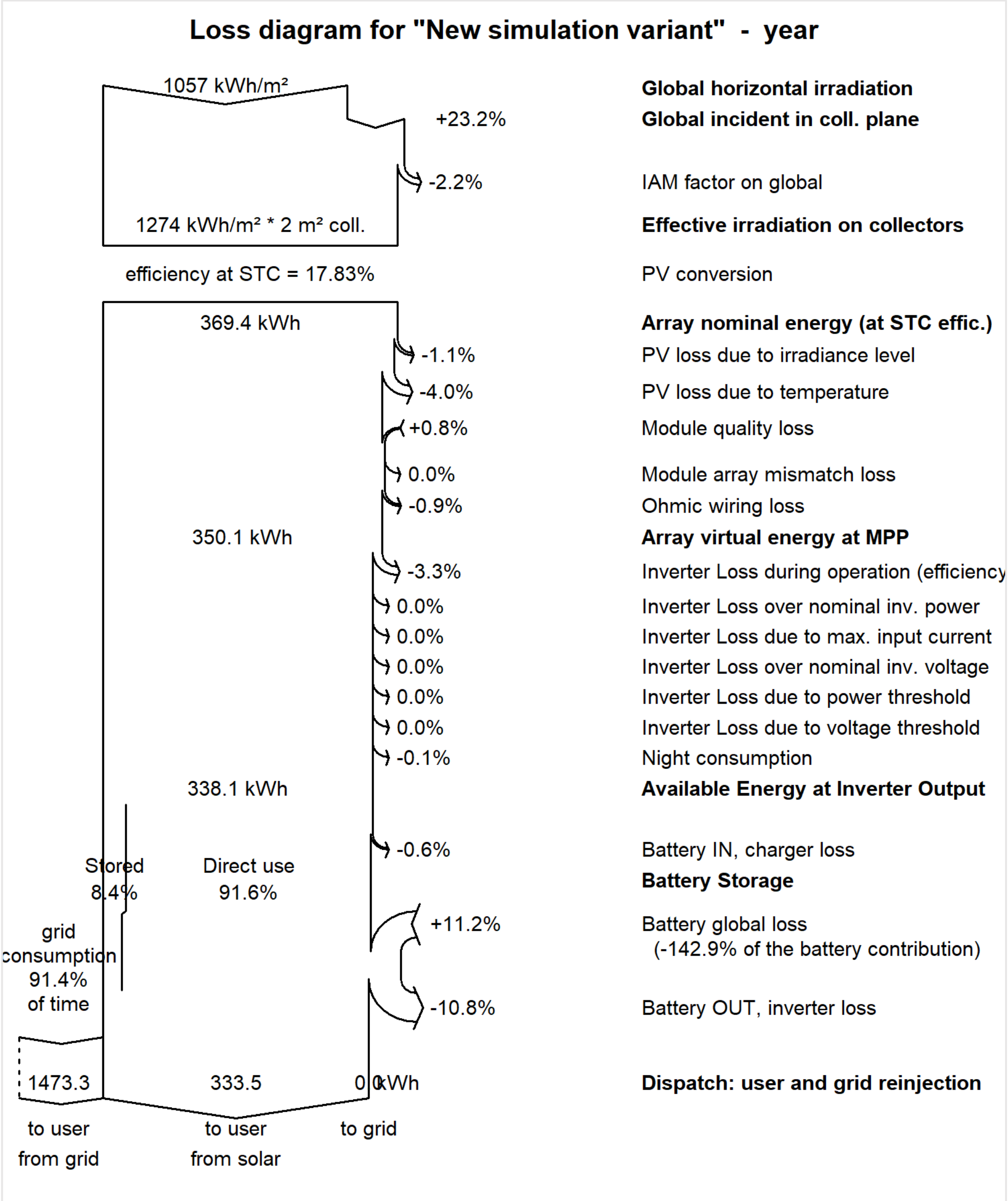
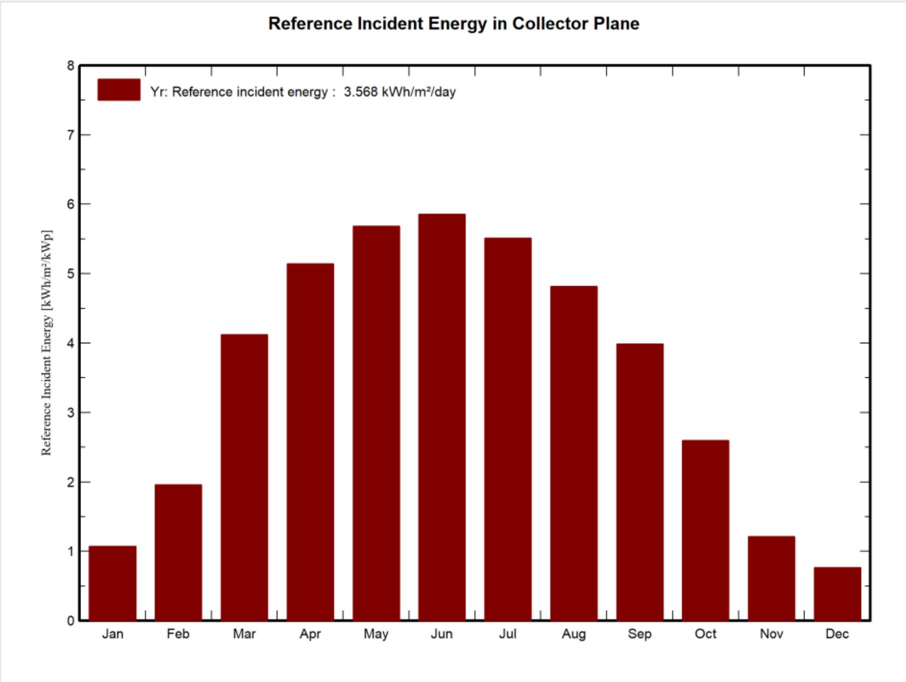
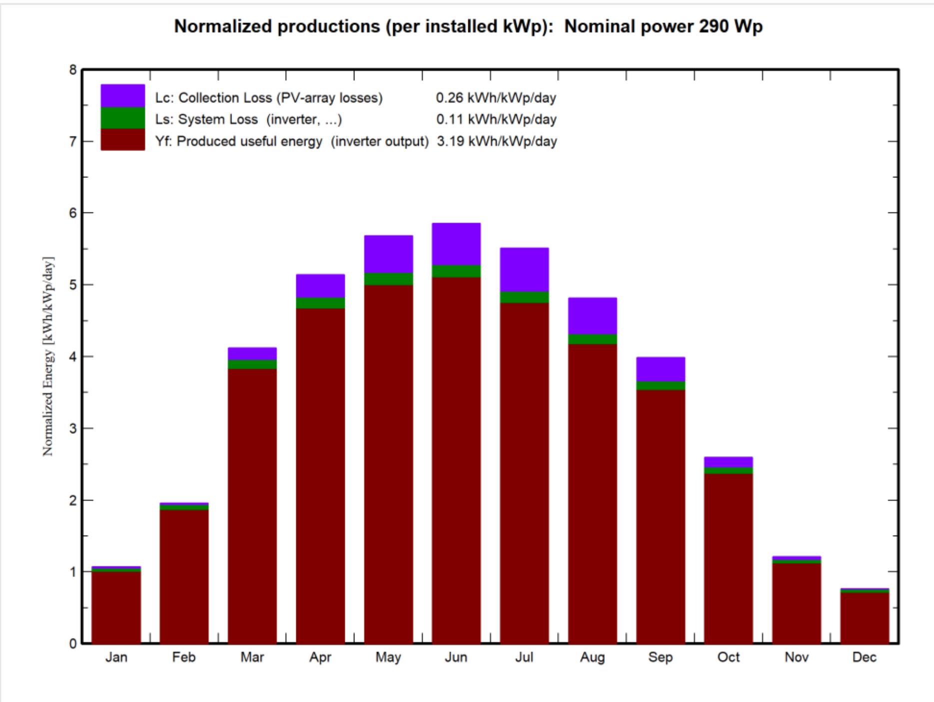


Figure 0.47 reference incident energy in collector 2022.



Based on the simulation of incident energy at the collector plate, the annual average amount was approximately 3.56 KWH/M^2/DAY. The lowest recorded rate occurred in December at around 0.9 KWH/M^2/DAY, while the highest was observed in the month of Jun, reaching approximately 5.80 KWH/M^2/DAY.

Figure 0.48 normalized productions 2022



According to the simulated diagram, the inverter exhibited the highest output in the month of Jun, reaching 5 kWh/Wp/day, while the lowest output was recorded in December at 0.8 kWh/Wp/day. The average daily production amounted to 3.19 kWh/Wp/day. It's noteworthy that the highest losses in arrays and inverters occurred in the month of Zone, whereas the lowest losses were observed in December. This observation suggests that an increase in production is associated with a corresponding increase in losses in both the inverter and cells.

Figure 0.49 normalized production and loss factors 2022.

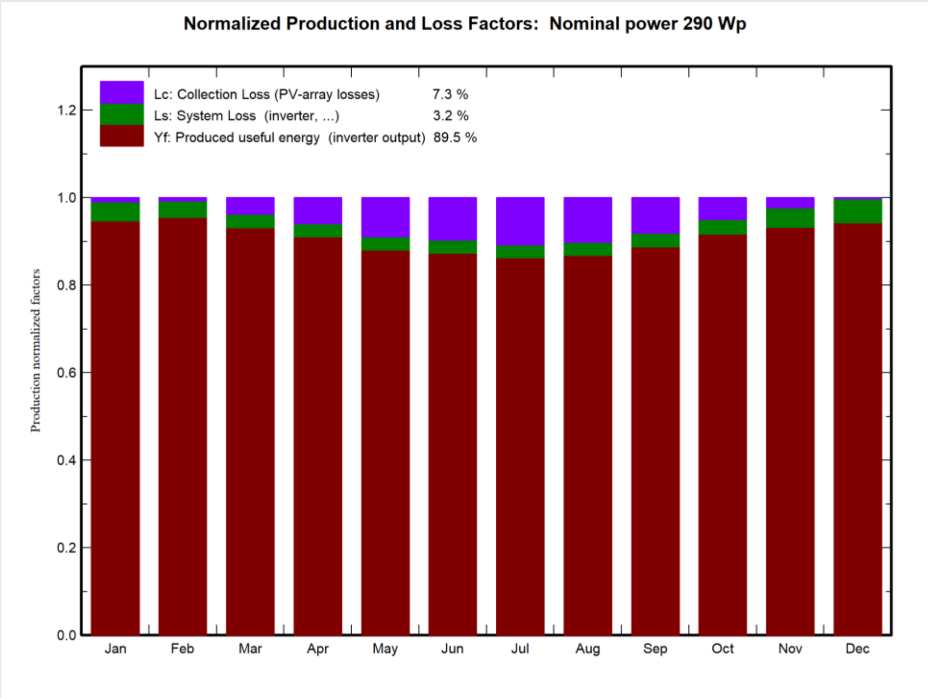
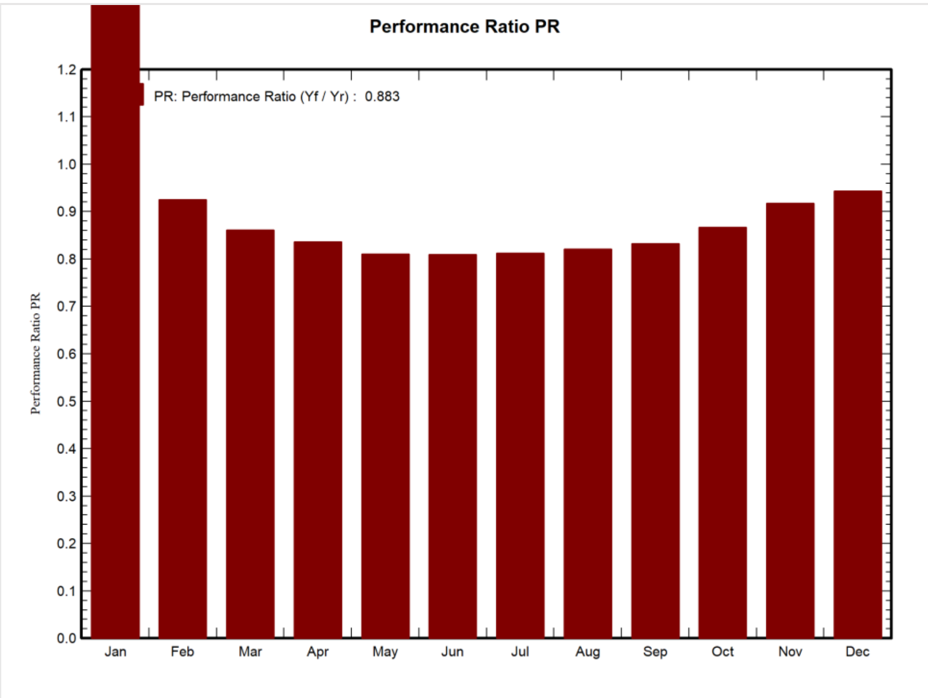
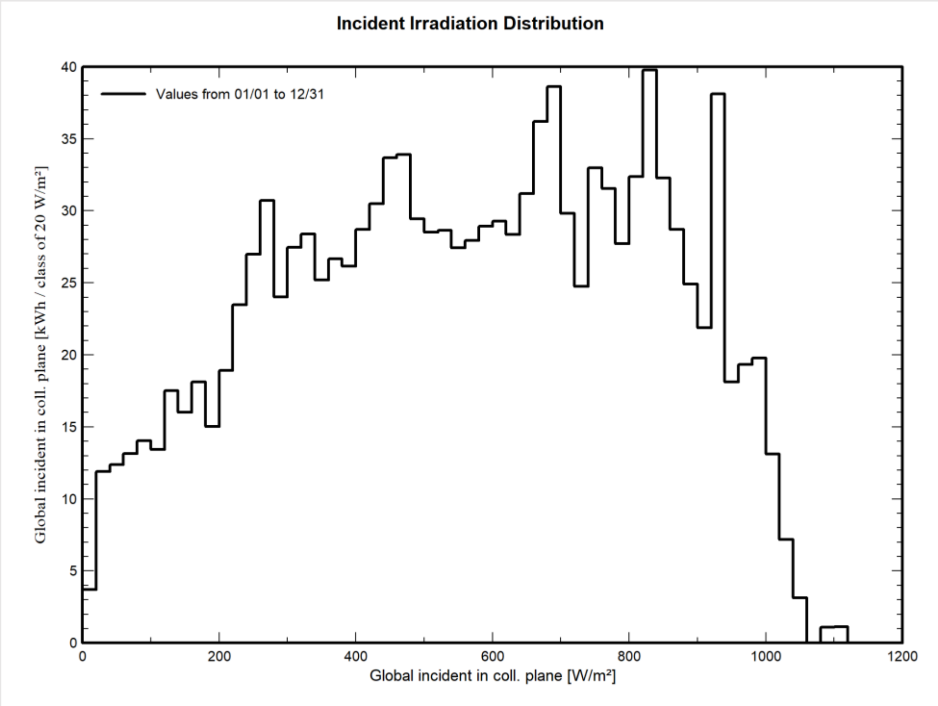


Figure 0.50 performance ratio PR 2022.



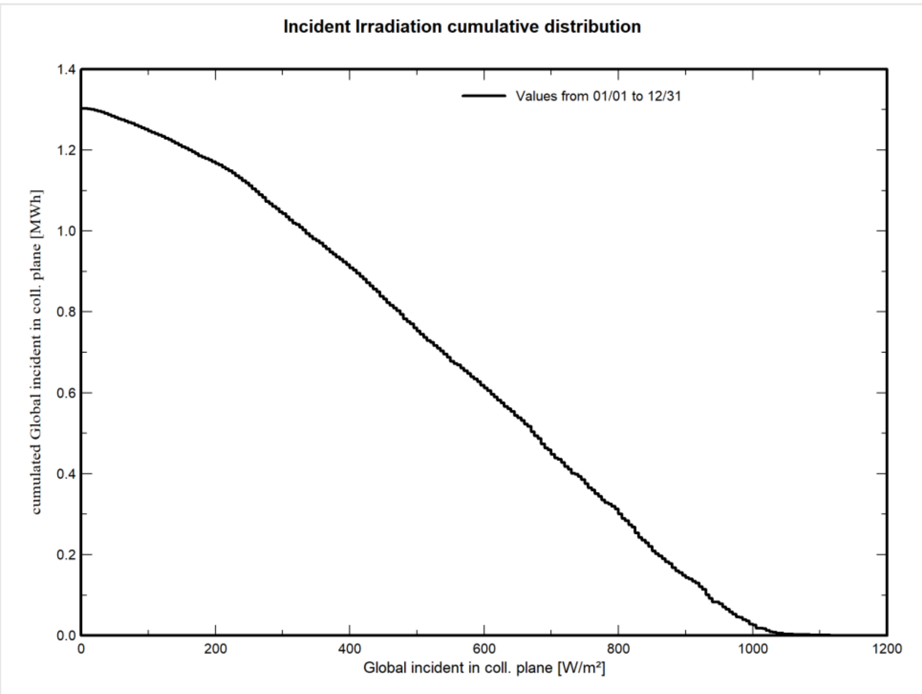
According to the simulated graph, the average performance of the system throughout the year is approximately 0.88. The highest efficiency occurs in January, reaching about 1.6, while the lowest efficiency is around 0.83 in the month of July. These values reflect the system's performance and efficiency under the influence of various factors and favorable conditions for production.

Figure 0.51 incident irradiation distribution 2022.



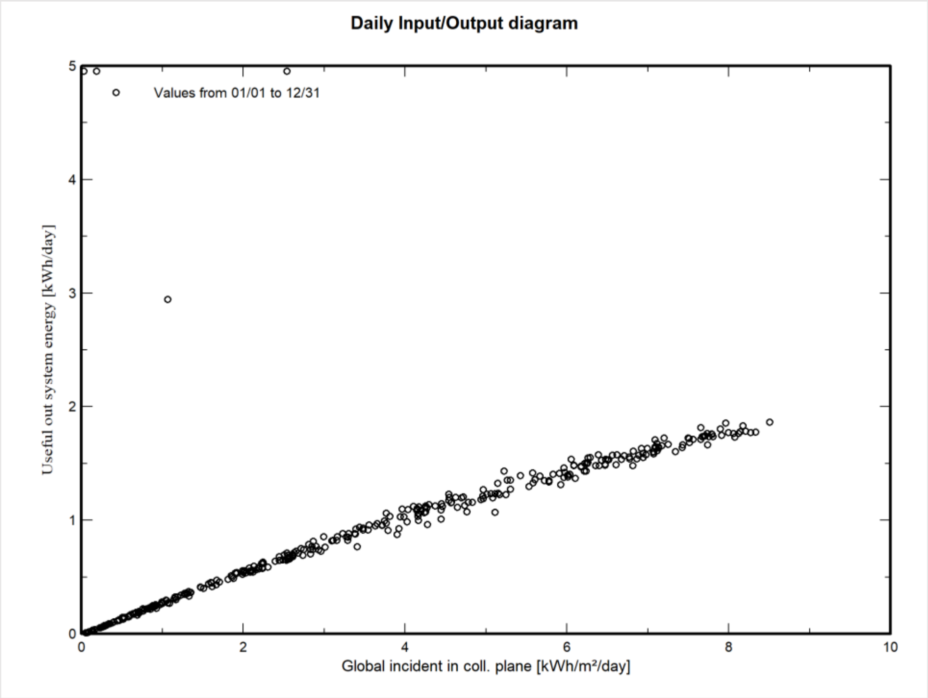
This diagram illustrates the direct correlation between the vertically received radiation on the solar cell and the total radiation received from all directions and the surrounding environment. Transitioning from colder months to warmer days is associated with an increase in the total radiation, consequently leading to an increase in the system's output.

Figure 0.52 incident Irradiation cumulative distribution 2022.



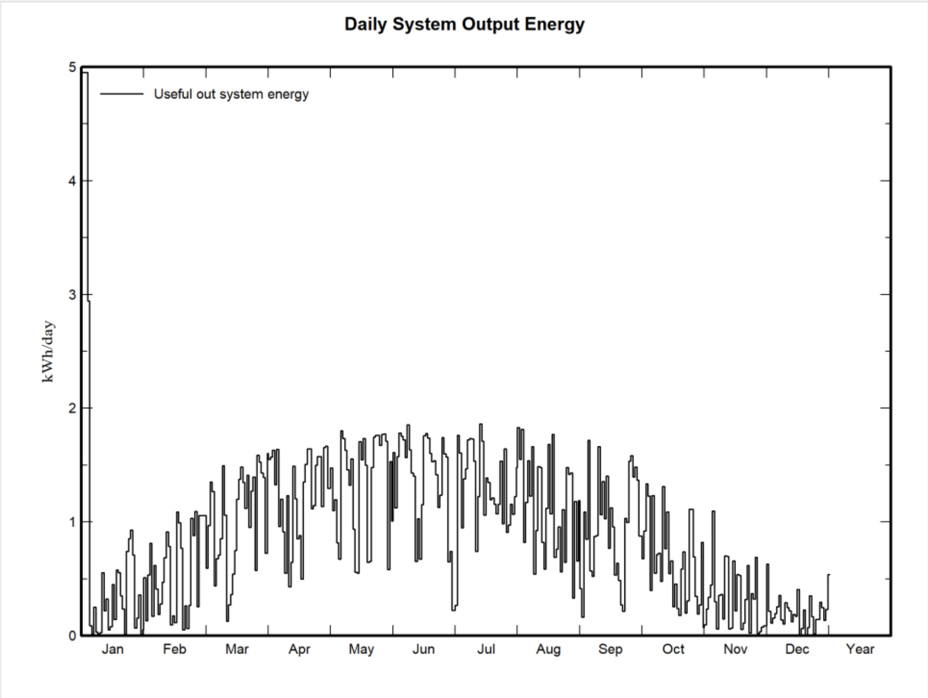
This simulation proves the hypothesis that as the total amount of radiation increases in all directions, the same amount of output increases in any period. It is the highest amount of total radiation.

Figure 0.53. daily input/output diagram 2022.



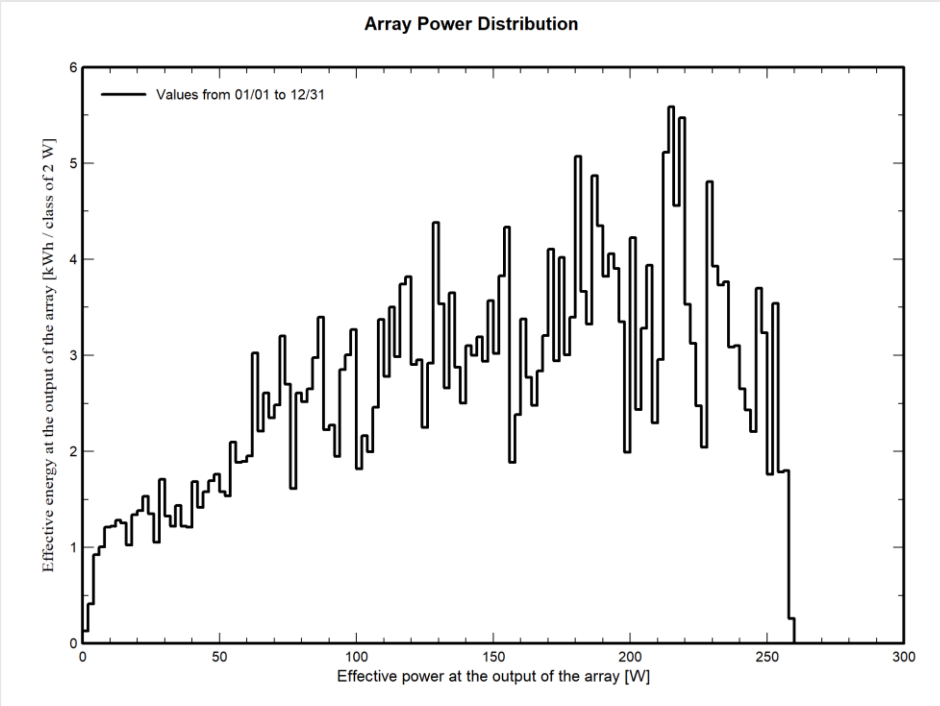
This simulated graph illustrates the daily production and system output, which increases progressively from the beginning of the year, reflecting the transition from colder to warmer seasons. It's important to note that "all the received light" refers to the total incident radiation on the panels, encompassing radiation received at a 90-degree angle and from all directions around the cell. In this simulation, by reducing the total amount of received radiation, the efficiency and output tone are reduced, and this theory is proved by comparison with the previous scenario.

Figure 0.54 daily system output energy 2022.



According to this simulated diagram, the system output experiences an increase in March, maintaining a favorable level with some fluctuations until the middle of October. Subsequently, the daily output gradually declines, reaching its lowest point in the middle and late days of December.

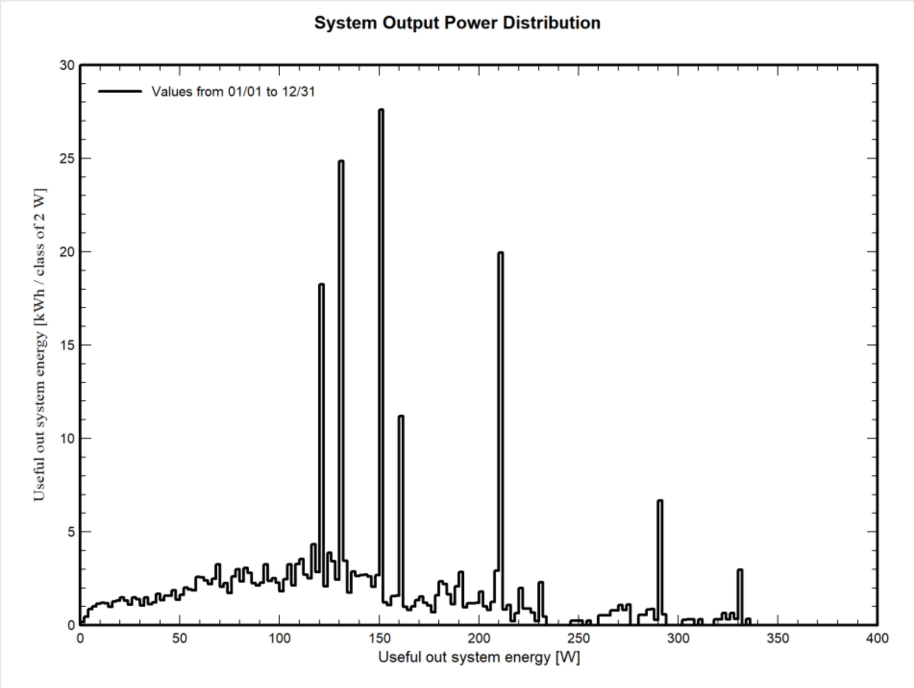
Figure 0.55 array power distribution 2022.



This graph illustrates the correlation between the effective power output from the arrays, measured in watts at specific moments, throughout the entire year. The corresponding data is then compared to the cumulative effective energy output in the system, measured in kilowatt-hours. Based on the previously provided diagram and explanations, considering influential environmental factors and the role of control equipment, it can be inferred that as temperature rises and solar panel radiation increases, the effective power output from the arrays demonstrates a proportional increase, resulting in a corresponding rise in the overall energy output from the entire system. This relationship is direct and indicates a positive correlation between environmental conditions, array power output, and system energy generation. This increase continues from day 60 to 230 and has the highest output on day 215.

Effective Energy (kWh)=Effective Power (kW)×Time (hours)

Figure 0.56 system output power distribution 2022.



The diagram illustrates the direct impact of the solar system's efficiency on the energy output for the consumption of electrical devices and the energy stored in batteries. As depicted in the graph, higher levels of received radiation led to increased energy output for both network consumption and battery storage. This correlation highlights the crucial role of system efficiency in maximizing the utilization of solar energy, particularly on days with elevated radiation levels. (increase from day number 120 to 220-but maximum days are:120-130-150-210-280)

Figure 0.57 system output power cumulative distribution 2022.

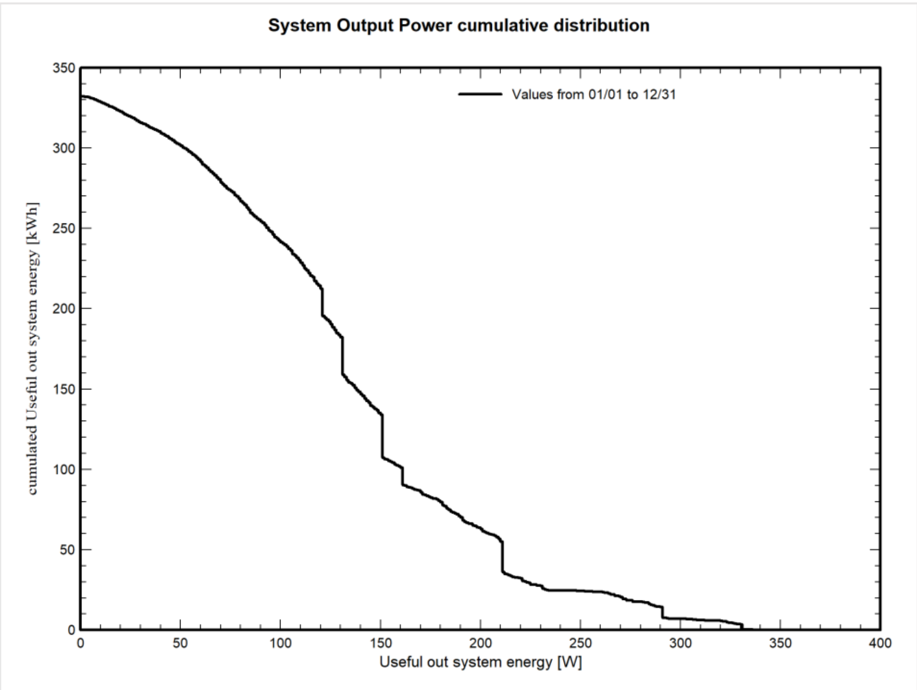
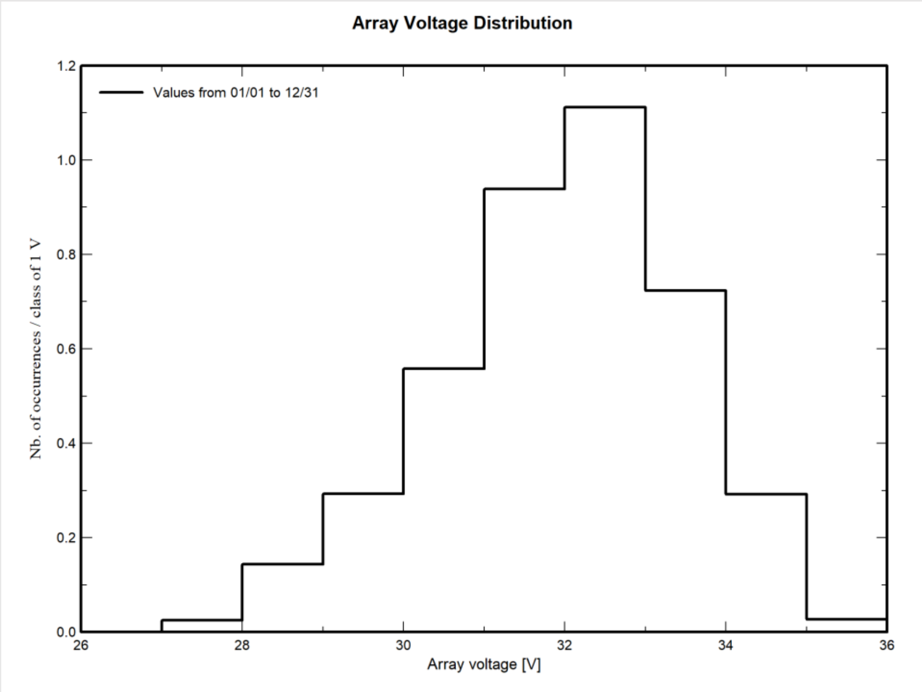


Figure 0.58 Array voltage distribution2022.



This simulation shows that the voltage has increased in two values from the defined or expected level. This increase is not pleasant and increases the probability of an accident.

Co2 emission:

Table 43. Co2 details. 2022

SYSTEM LIFECYCLE EMISSIONS DETAILS			
item	**LCE**	**QUANTITY**	**SUBTOTAL**
			(kgco2)
modules	**1713kgCO2/Kwp**	**0.29kWp**	**497**
supports	**2.57kgCO2/kg**	**10.00kg**	**25.7**
inverters	**254kgCO2/units**	**1.00unit**	**254**

Comparing the results of important factors for scenarios 4 and 5:

Table 44. Comparing the results of important factors for scenarios 4 and 5:

factors	Scenario 4(based on 2023data)	Scenario 5(based on 2022 data)
Tilt/azimuth	45°/0	40°/0
Daily profile average	6.1 KWH/DAY	4.9kwh
Pnom total	290 wp	290 wp
Global horizontal irradiation	1057 kwh/m^2/day	1057 kwh/m^2/day
Array nominal energy	394 kwh	394 kwh
Array virtual energy at MPP	350.1 kwh	350.1 kwh
Available energy at the inverter output	338.1 kwh	338.1 kwh
Battery storage	93.60%	91.60%
dispatch	333.9	333.5
Reference incident energy in collector plane	3.568 kwh/Kwp/day	3.568 kwh/Kwp/day
Product useful energy (invertor out)	3.19 kwh/Kwp/day	3.19 kwh/Kwp/day
System loss	0.11 kwh/Kwp/day	0.11 kwh/Kwp/day
Performance ratio PR	0.884(88.4%)	0.883(88.3%)
System output power distribution in maximum day	31 kwh	28 kwh
Produced Energy	333.87 KWH/YEAR.	333.45 KWH/YEAR.
Specific production:	1151 KWH/KWP/YEAR	1150 KWH/KWP/YEAR.
SYSTEM PRODUCTION	333.45 KWH/YEAR.	333.45 KWH/YEAR.

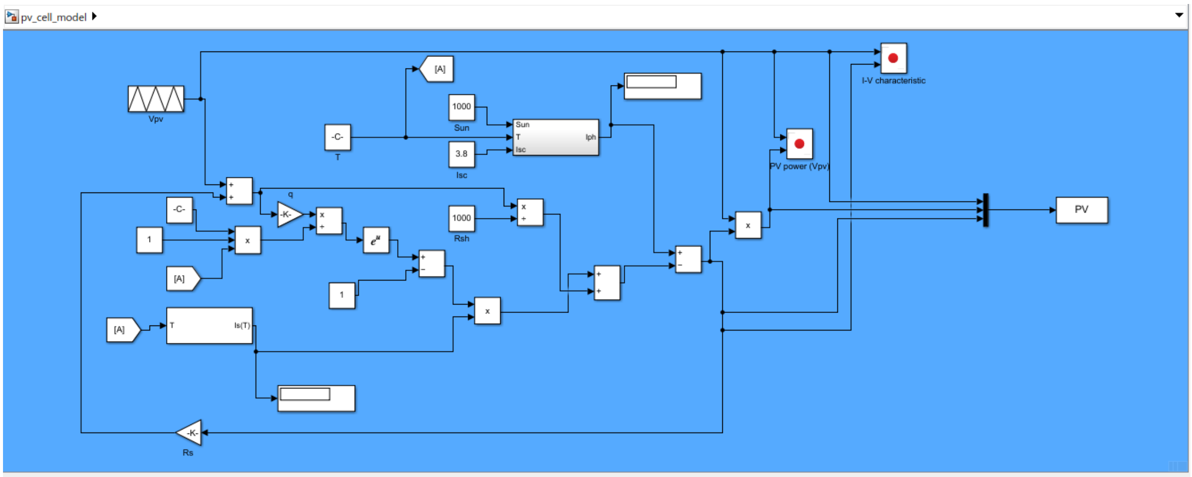
3.23. Simulation, calculations, and analysis of the designed system in the MATLAB software:

In this section, we aim to simulate the designed solar cell system and develop a single cell, connecting it to a network of similar cells using MATLAB software. We will analyze the changes in factors discussed in previous scenarios. Additionally, we have examined the voltage-current relationships and how cell behaviors change with temperature variations. The results will be presented separately.

Part 1:

In this section, we have designed a diagram of a solar cell and its internal circuits, including resistors and diodes, to capture incoming radiation. As shown in the figure below, we have defined the output of the PV Power and the current-voltage characteristic ratio, and the results are presented in the form of a graph or chart.

Figure 0.59 PV CELL MODEL simulation with MATLAB:



In the diagram presented below, we have undertaken an examination of the impact of factors such as temperature, radiation, RS, RSH, and IS by extending and interconnecting the upper solar cell with a network of comparable cells.

In the realm of a photovoltaic (PV) system, RS, RSH, and IS constitute electrical parameters pivotal in determining the solar cells' behavior.

RS (Series Resistance):

RS, denoting series resistance, characterizes the resistance encountered within the internal components of the solar cell during the flow of current. These components encompass semiconductor materials and metal contacts. Although RS typically assumes a small value, its influence on the overall efficiency of a solar cell can be substantial. Elevated RS may induce a voltage drop in the solar cell, consequently reducing its output voltage.

RSH (Shunt Resistance):

RSH, or shunt resistance, signifies the resistance across the terminals of a solar cell when it is not exposed to sunlight. In simpler terms, it denotes the resistance existing between the front and rear contacts of the cell. Typically, RSH maintains a high value, and a preference exists for a higher RSH as it minimizes leakage current during the cell's dark phase. Conversely, a low RSH may lead to a "shunting" effect, enabling a portion of the current to bypass the solar cell, thereby diminishing its overall efficiency.

IS (Saturation Current):

IS, identified as saturation current, quantifies the reverse or dark bias current in a solar cell not exposed to sunlight. It functions as a measure of the leakage current within the solar cell. A lower IS implies enhanced performance of the solar cell in the absence of sunlight.

These parameters hold significant importance for modeling and scrutinizing the behavior of solar cells under diverse conditions. They find application in equations such as the Shockley-Queisser equation, facilitating the prediction of the maximum theoretical efficiency of a solar cell and the optimization of its design for real-world applications.

Figure 0.60 PV ARAY MODEL simulation with MATLAB:

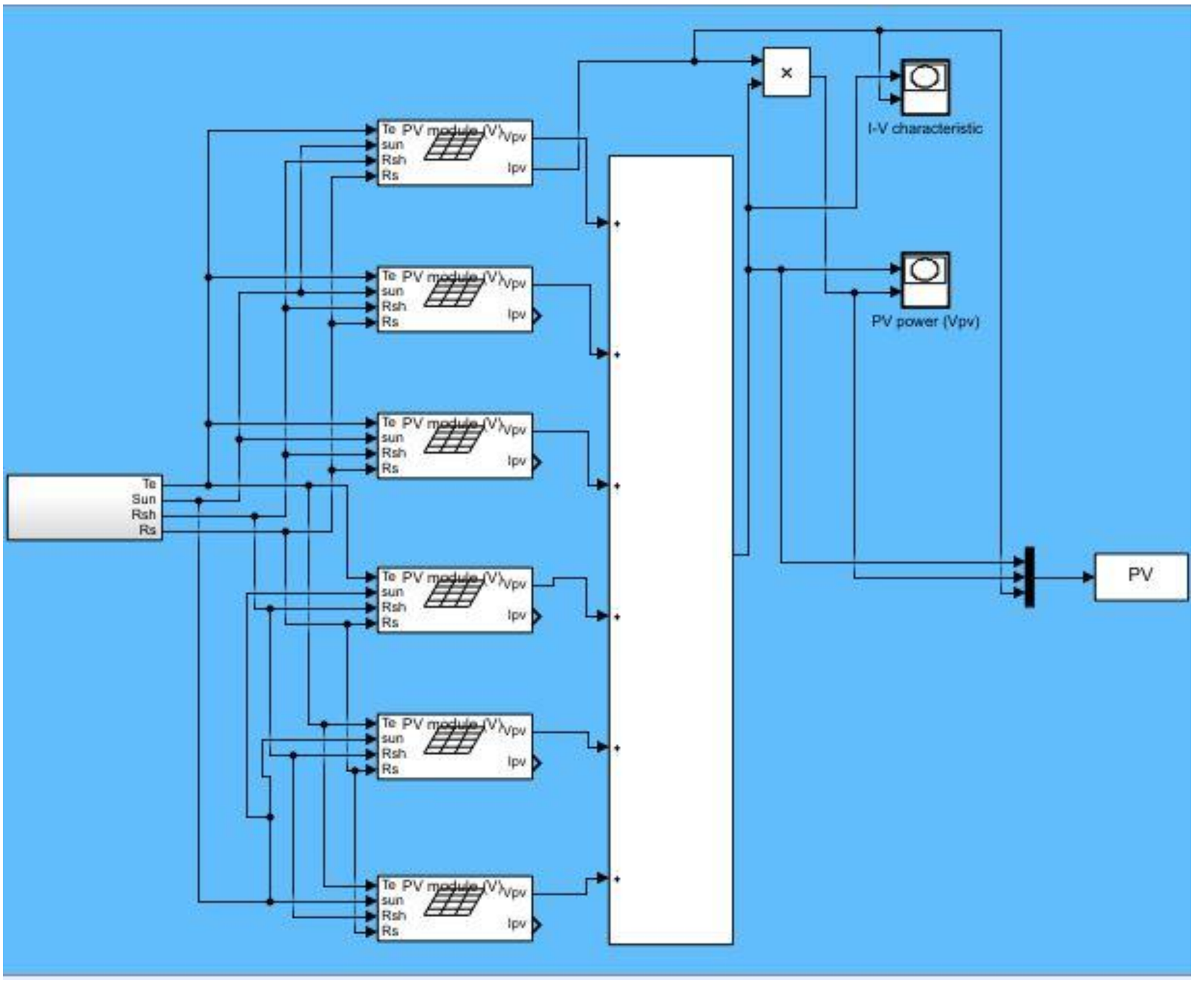


Figure 0.61 array of PV model P290 Wp60 cells

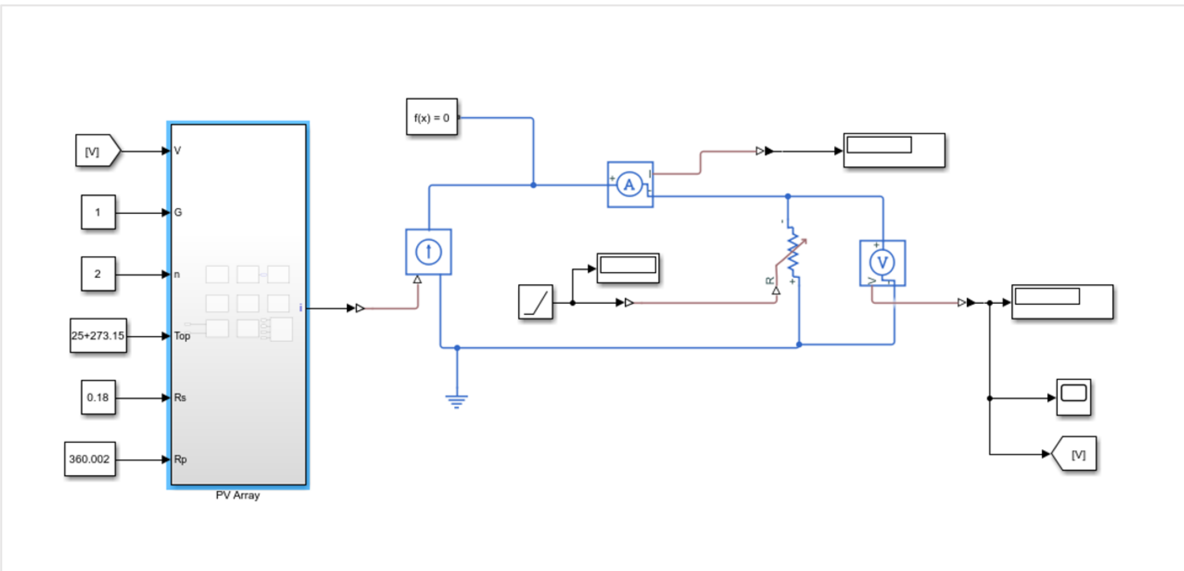


Figure 0.62 PV CELL EFFECT OF SOLAR RADIATION simulation with MATLAB:

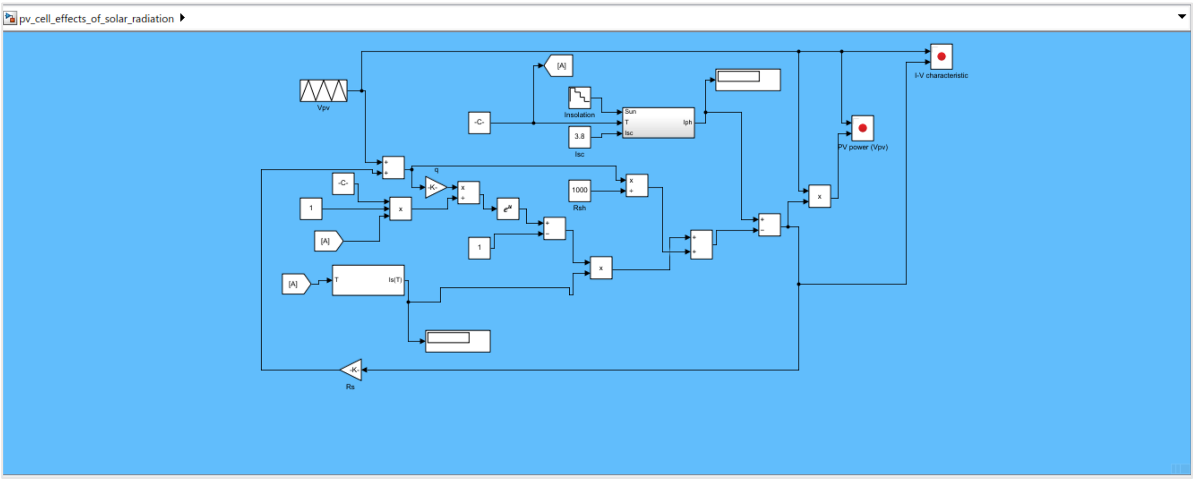
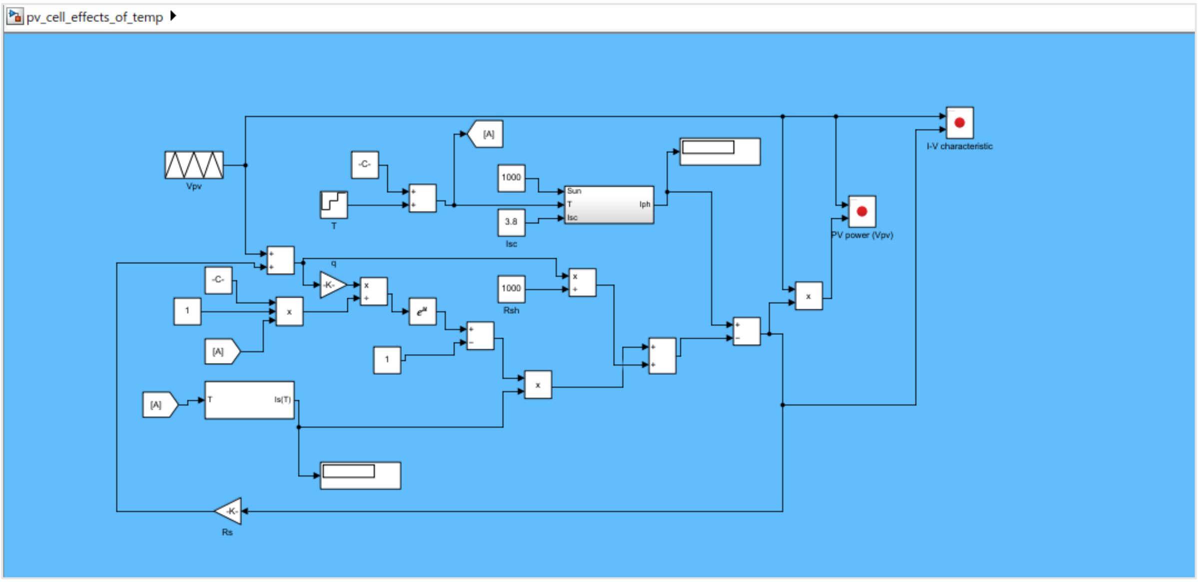
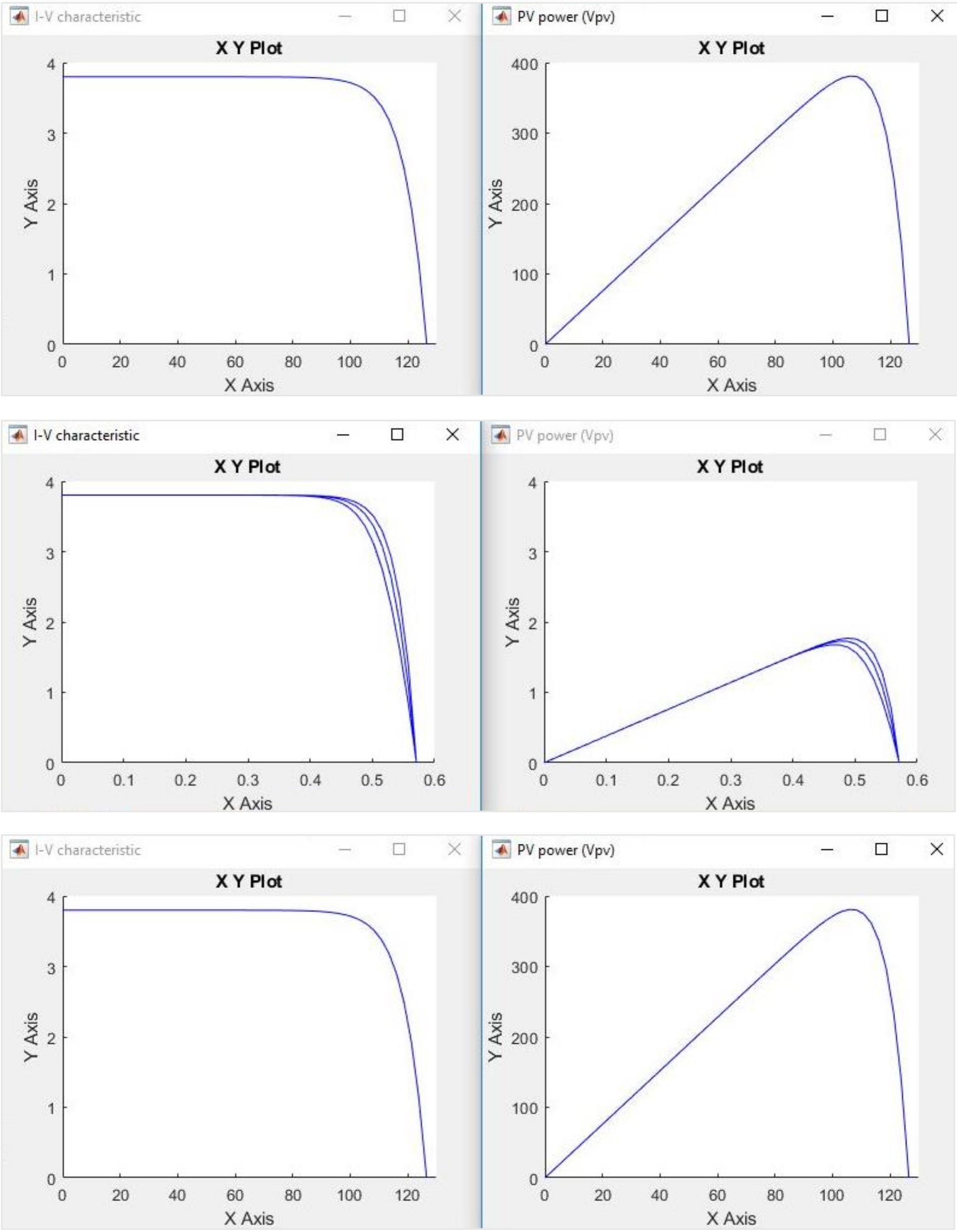


Figure 3.63 PV CELL EFFECT OF TEMPERATURE simulation with MATLAB:



In the figure below, the variations in the factors and their impact on the performance of solar cells are depicted, with a breakdown of each factor extracted from MATLAB software.

Figure 0.64 I(ampere) AND V(voltage) CHARACTERS AFTER WE ARE VARYING Rs AND Rsh simulation with MATLAB:



3.24 What is mismatch and why is important?

The "mismatch" phenomenon, or the mismatch of solar cells, is a common occurrence when connecting solar panels.

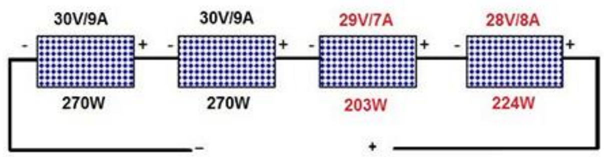
In solar power plants, panels are generally connected in series or parallel to achieve higher power. When dissimilar panels (in terms of current and voltage) are connected in series or parallel, the current in the series connection is limited to the lowest panel's current, and in parallel, the voltage across the circuit is restricted to the panel with the least potential difference. Therefore, during the design of solar systems, a strong recommendation is to connect solar panels with similar voltage and current parameters to prevent power losses and maintain the efficiency of the power plant.

However, a subtle point exists here. Even when solar panels with the same power, and even from the same brand, are connected in series or parallel, due to the different voltage-current curves of the solar cells, the mismatch phenomenon occurs on a small scale and at a low percentage. This, nevertheless, results in a power drop. For example, a 270-watt solar panel expected to provide 30 volts and 9 amps may have slightly lower voltage or current, impacting the entire solar system connected in series or parallel.

Consider the following examples. In the first example, four similar 270-watt solar panels are connected in series, but two of them do not have perfect matching, operating with slightly lower voltage and current than required. The calculations show that the mismatch or loss phenomenon has caused a few percentage drops in the total power.

Impact of mismatched solar panels in series:

Figure 0.65. impact of mismatched solar panels in series((https://hoorayesh.com/mismatch-of-solar-panels/, https://hoorayesh.com, 2023)



Total voltage: 117 volts = (2 × 30) + 29 + 28

Total current: 7A

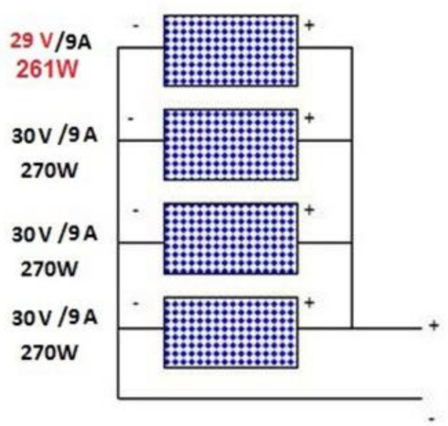
Total power: 819W (117 × 7)

Note that if the power of the panels were perfect, the total power would have been 1080W, meaning a 24% decrease!

In the second example, where the panels are connected in parallel, the calculations again reveal a small percentage decrease in total power due to the mismatch.

Impact of mismatched solar panels in parallel:

Figure 0.66 Impact of mismatched solar panels in parallel((https://hoorayesh.com/mismatch-of-solar-panels/, https://hoorayesh.com, 2023)



Total voltage: 29 volts

Total current: 36 amps = 4 × 9A

Total power: 1044W (29 × 36)

Note that if the power of the panels were perfect, the total power would have been 1080W, indicating a 3% decrease!

Despite these losses, addressing the mismatch phenomenon is not something that can be eliminated. However, ensuring a high-quality and consistent degree in solar panel manufacturing and purchasing from reputable brands can help mitigate these losses. In solar system design software such as PVSYST, these losses are often considered to be around 1%.

Chapter 4 Demand:

The focus of this chapter is on consumption analysis, and we have used three distinct approaches rooted in our project methodology. To precisely simulate this data, we used MATLAB and Excel and created consumption patterns for each apartment on an hourly, daily, weekly, monthly, and yearly basis.

We recognize that various factors can affect consumption levels and while we assessed these factors using the Vensim software, we acknowledge that fixed-value simulations cannot capture real-world fluctuations based on field data. Therefore, we documented available data from a real consumer affiliated with the NRGI company and analyzed this consumer's behavior within a specific timeframe, covering the last two years, 2022 and 2023.

As this data is documented, real, and field-based, we used it in scenarios six and seven to analyze the system's behavior in response to this data.

4.1 Determining the consumption domain based on actual customer documents received from the company NRGI AALBORG CITY.

In this section, with reference to the documented information and data we have received from NRGI company in the city of Aalborg, we thoroughly examine the consumption domain. It should be noted that scenarios 6 and 7 have been calculated based on this consumption domain. All the information related to this section is documented and obtained from the relevant company's Excel file. 4.2.1 Data 2022.

in the first section, consumption data for the year 2022 is analyzed. The month of April is randomly selected as the consumption domain. This month serves as the basis for scenarios 4and 5 for the years 2022 and 2023. Subsequently, an hourly analysis for the month of April in the year 2022 is conducted, followed by a daily consumption analysis throughout the year and month by month. The results are presented in graphs as follows.

Figure 4.1 hourly 1-04-2022

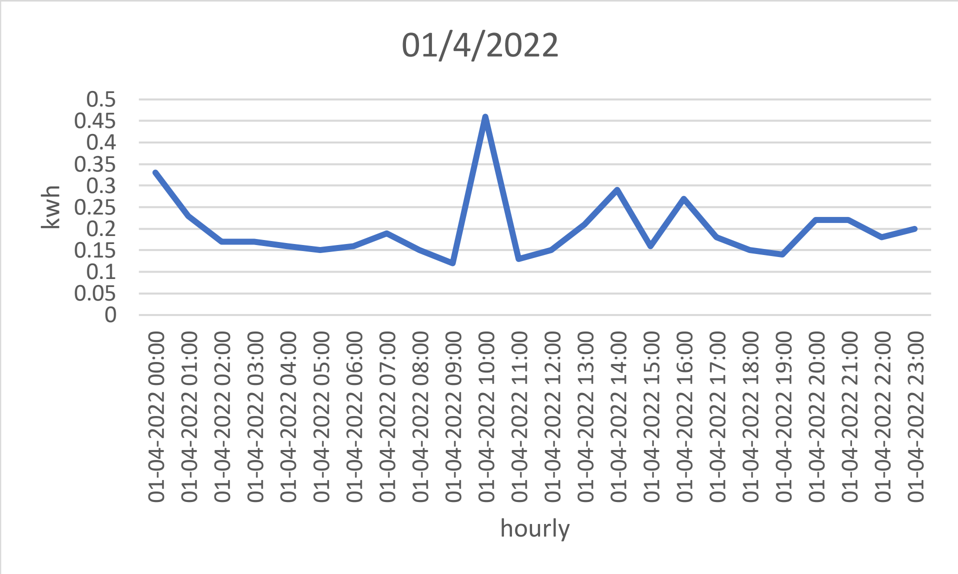


Figure.4.2. April 202.days with hourly

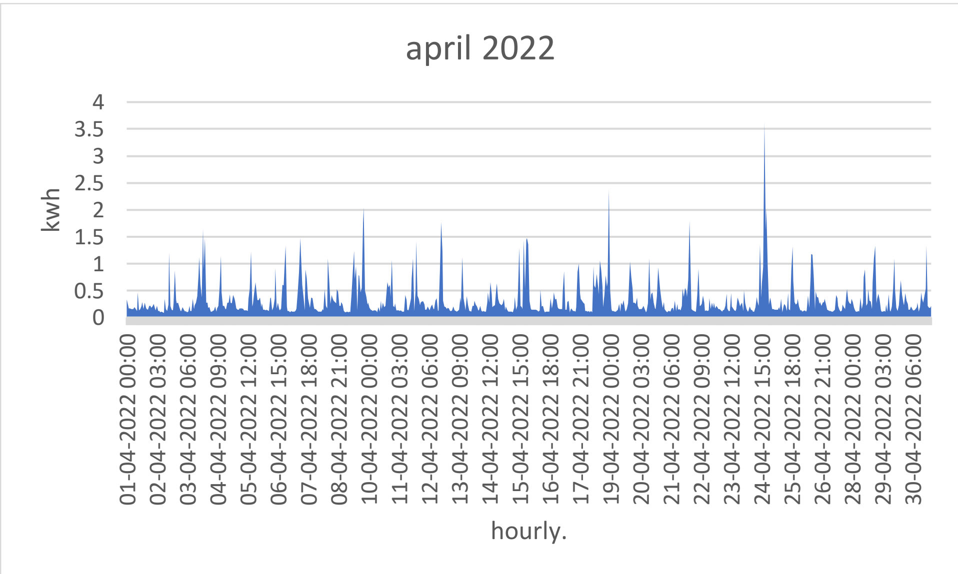


Figure 4.3. Daily consumption from April to September

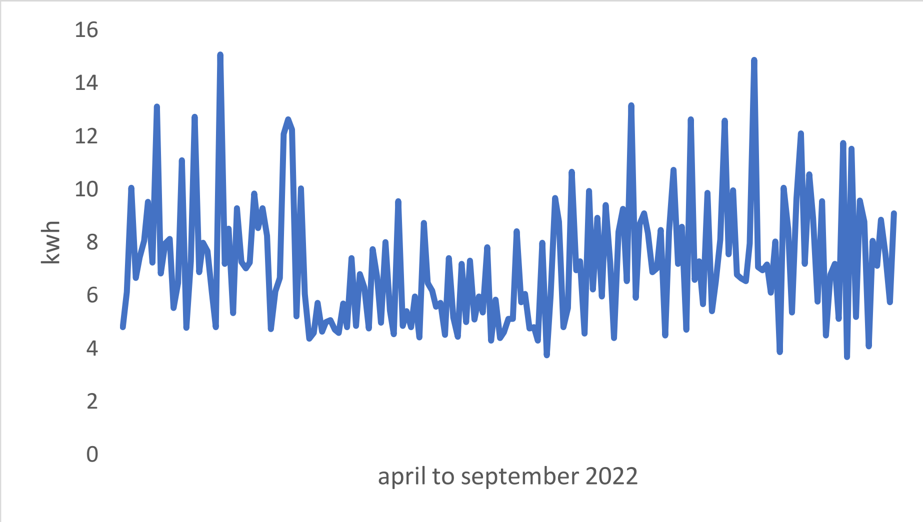
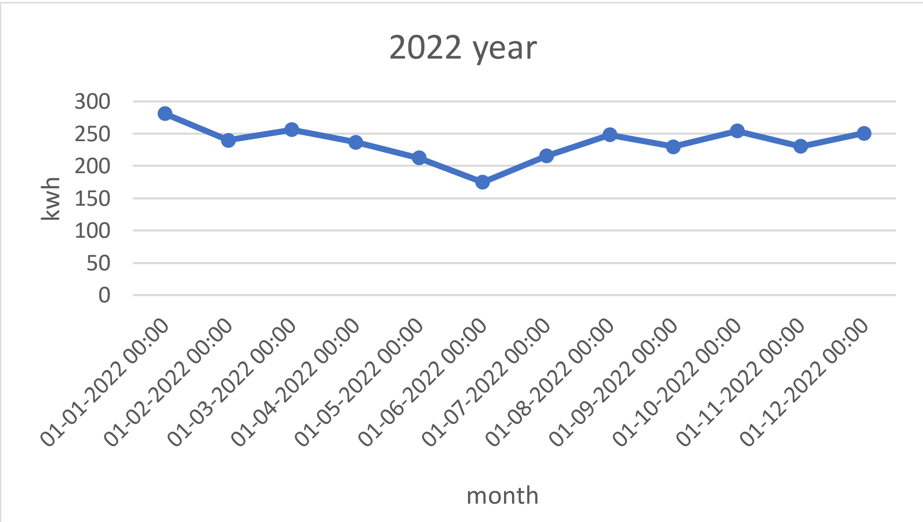


Figure 4.4. 2022 monthly



4.2.2 DATA 2023.

Figure 4.5. hourly 01-04-2023.

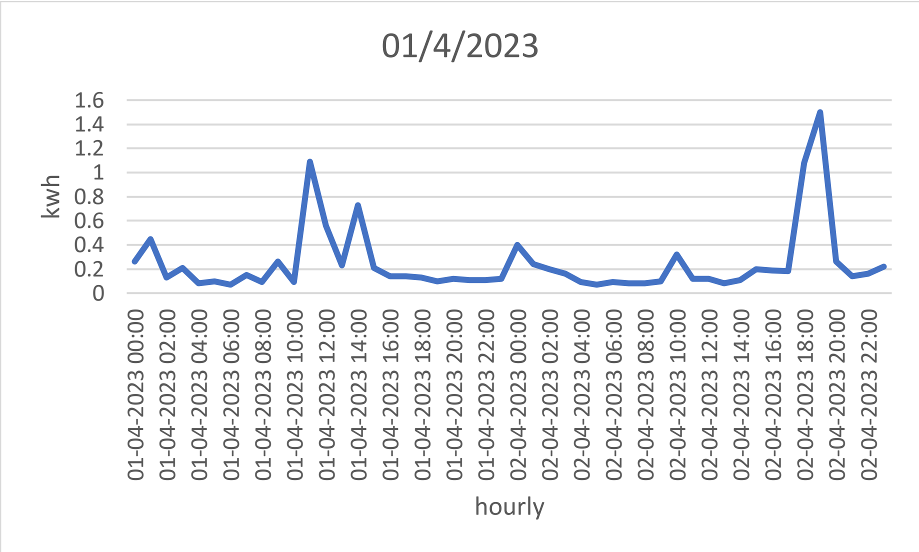


Figure 4.6. April 2023.daily

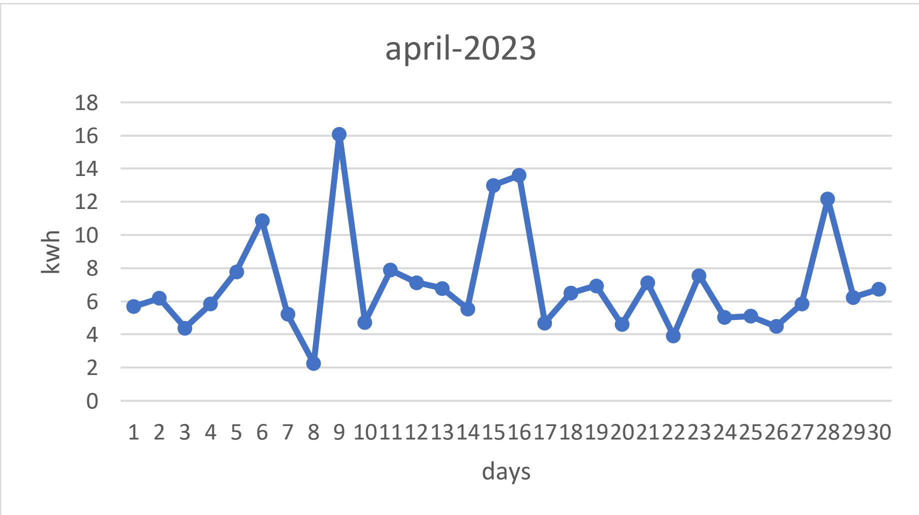


Figure 4.7. April 2023. hourly

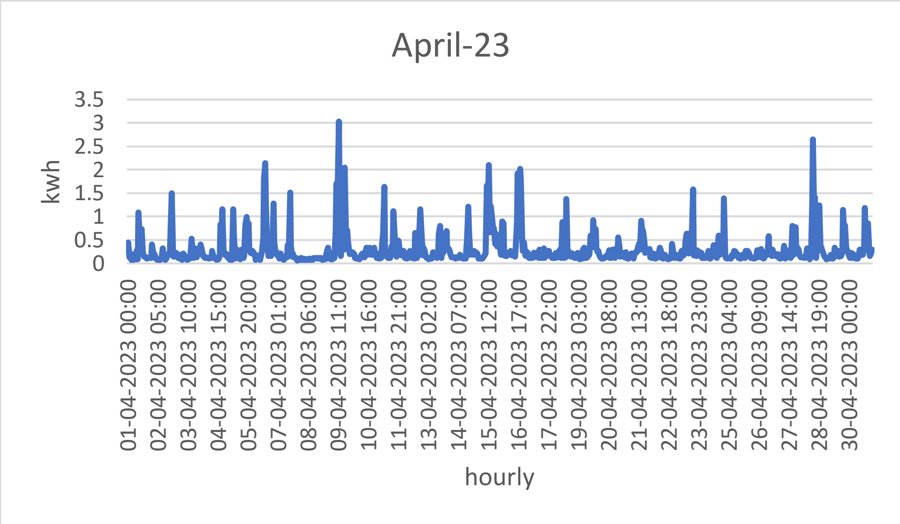
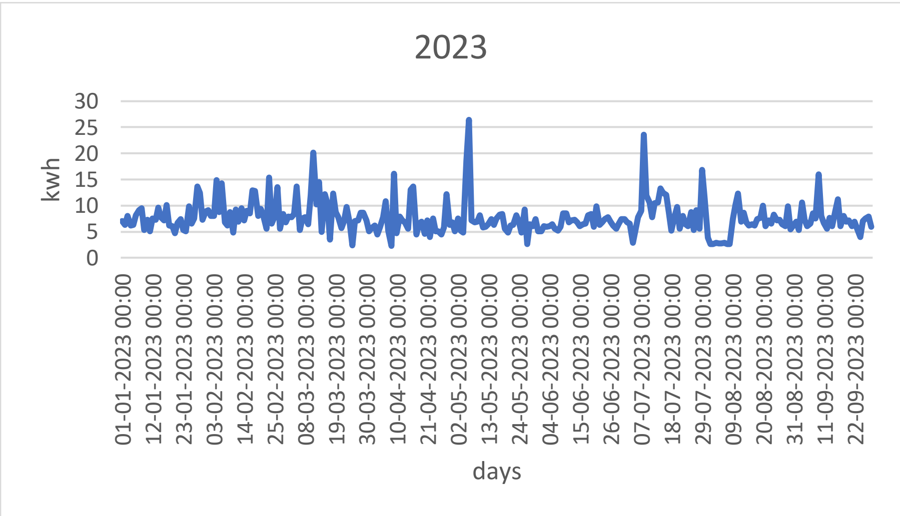


Figure.4.8 daily 2023.



Chapter 5 Battery:

5.1. The Role of Batteries in Renewable Systems:

They assume a pivotal role in formulating the strategy for harnessing renewable energies. Batteries emerge as the foremost component in establishing equilibrium between demand and consumption, particularly during peak consumption periods within the network. Their significance becomes more pronounced considering the intermittent nature of renewable energies, where the method of storage stands as a critical consideration for economic and security justifications of projects. The primary criteria for classifying batteries hinge on factors such as charging time, discharge rate, and the frequency of this phenomenon.

Diverse Battery Capacities:

Batteries for renewable energy systems come in various capacities. Essentially, batteries act as reservoirs for storing excess energy when renewable systems are overproducing, and they play a crucial role in supplying power to consumers. Hence, selecting the right battery capacity is paramount for consumers.

Battery Varieties:

The choice of battery type in renewable energy systems depends on the specific renewable setup, budget considerations, and fluctuating energy requirements. A range of battery types can be used for energy storage in renewable systems. For instance, lithium-ion batteries, known for their high charge and discharge capabilities and lightweight design, may offer longer lifespans compared to bulkier alternatives. Given their extended lifespan and rapid charging capabilities, lithium-ion batteries are well-suited for renewable systems, although they come with a higher price tag, which may not be cost-effective for all users.

Another viable option is AGM (Absorbent Glass Mat) batteries, which are notable for their high efficiency, reasonable pricing, and durability. These batteries can withstand temperature fluctuations, ensure stability, and provide enhanced safety features, making them a favorable choice for renewable energy systems.

5.2. Battery behavior:

Initially, a schematic depicting the single-line connection of batteries within the system is presented. As previously discussed in scenarios 4 and 5, these two scenarios involve the integration of batteries into our system, encompassing charging, discharging, and operational phases to facilitate an analysis of battery performance. In scenario 4, we scrutinize the behavior of a lithium-ion battery, while scenario 5 involves an analysis of two lithium-ion batteries connected in series. Both batteries possess comparable capacities. To assess the battery's performance, it is essential to establish a consumption profile. As elucidated in the production section, we have integrated data collected from 35 different devices over a 24-hour period into our simulations.

Batteries exhibit versatility in their operation, contingent on design strategies and customer requirements. This implies that batteries can function in diverse capacities, ranging from solely supporting the grid to storing energy during peak consumption periods or peak demand, as well as serving to isolate our grid from quasi-isolated power sources or isolating specific load segments. In this context, our analysis centers on local network consumption and isolation during peak demand periods, allowing us to scrutinize battery behavior. MATLAB software simulations have been employed for this analysis, delving into the battery's behavior, encompassing aspects like the current-voltage-power relationship, and the charging and discharging processes.

5.3. Lithium-ion Batteries:

These batteries harness highly advanced technology, with early prototypes entering the market as far back as the 1970s. Although they were initially predominantly employed in mobile phones, tablets, and laptops, they have seen a substantial surge in popularity in recent years for applications within the renewable energy sectors. Despite their considerably higher cost compared to other battery types, they present a multitude of benefits that rationalize their premium pricing.

Here are some of these benefits:

1. Exceptionally long lifespan.
2. Increased energy efficiency in power consumption.
3. Elimination of the need for regular maintenance and servicing.
4. Enhanced discharge capacity, allowing for higher storage.
5. Zero emissions.

It is commonly understood that the no-load voltage of a lithium battery should not drop below 3.0V or even reach as low as the maintenance range threshold value of around 2.8V. Some consider 3.2V as the threshold. Most lithium batteries should not be discharged below 3.2V to avoid potential over discharge, which can be detrimental to the battery. In the consumer market, lithium batteries are typically used with protection circuits to prevent over-discharge. Over-discharging can render the protection circuit ineffective, as it cannot detect the battery, and as a result, charging may become impossible.

The highest voltage at which a lithium battery should be charged is 4.2 volts. Generally, an unloaded lithium battery is charged up to 4.2 volts. During the charging process, the battery voltage gradually increases from 3.7 volts to 4.2 volts. It's crucial not to overcharge lithium batteries beyond 4.2 volts, as this can lead to battery damage, a critical consideration in lithium battery management. (https://www.thermofisher.com/dk/, 2023)

In figures numbered 5-1 to 5-4, the behavior of the selected lithium battery for the solar cell system, which is 26 volts and 180 ampere-hours, has been simulated and displayed based on charging, discharging, and battery discharge, and the ratio of the behavior of each of these factors. This simulation is based on a real tested sample. (The simulation was done by pvsyst7.4 software.)

Figure 5.3.1 The ratio of cell voltage to cstate of charge

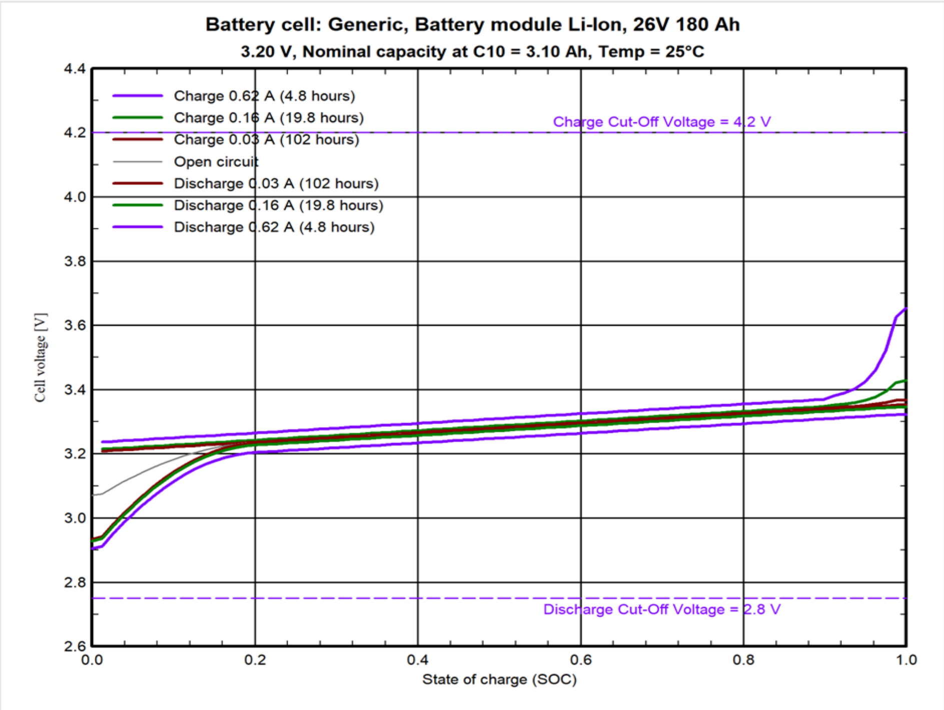


Figure 5.3.1 The ratio of cell voltage to charging time-

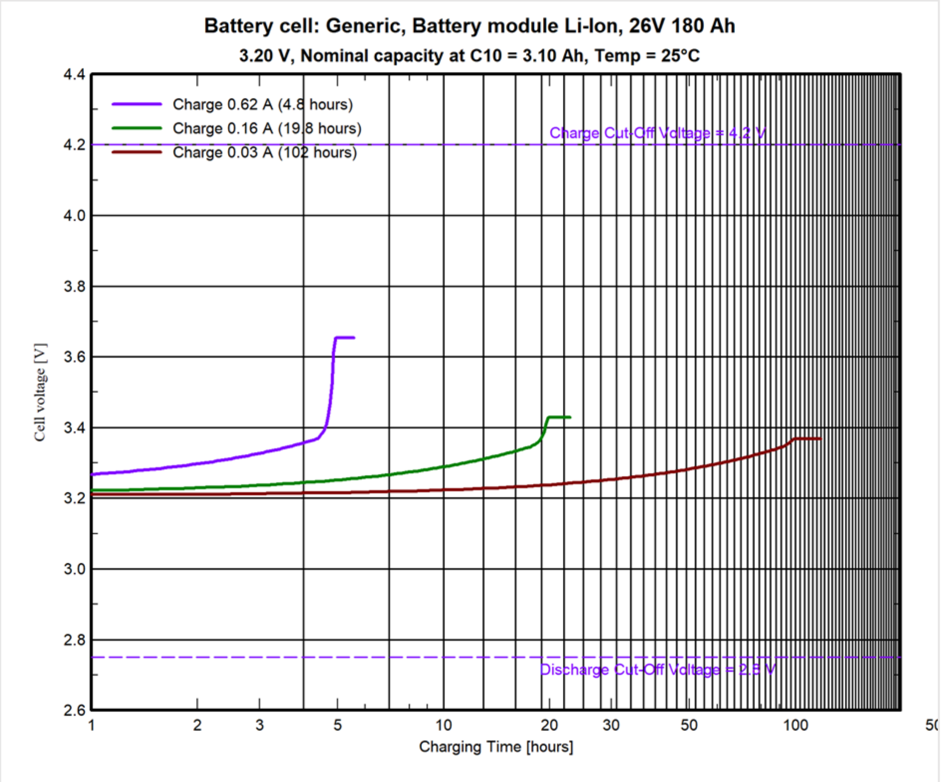


Figure 5.2.3 The ratio of cell voltage to charging time-

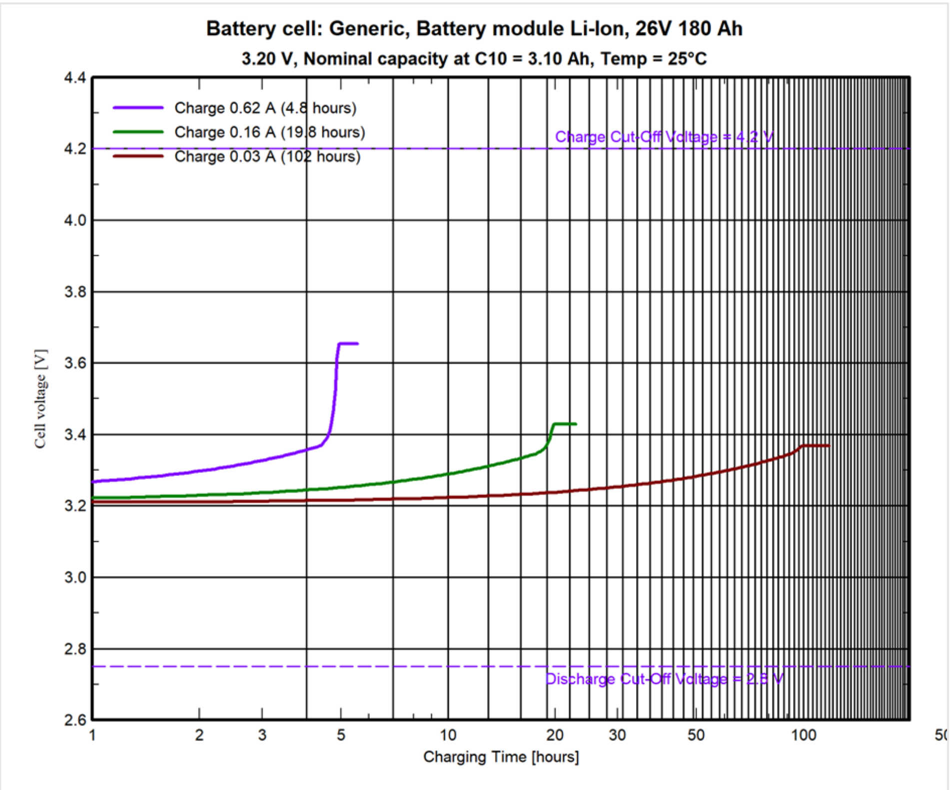
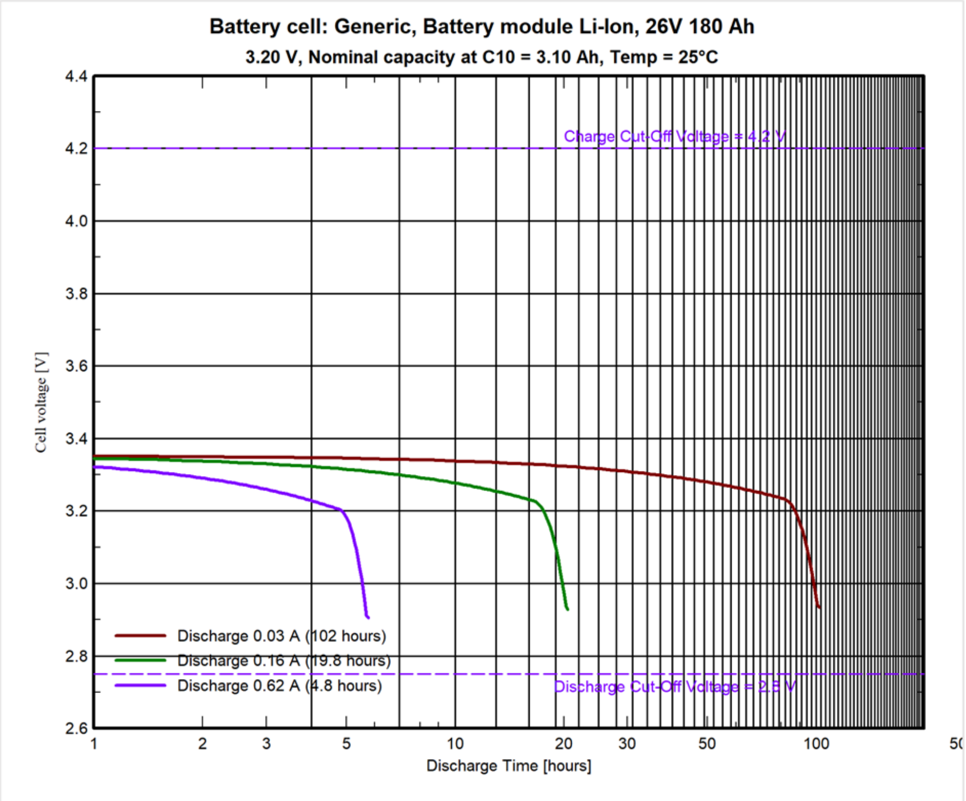


Figure 5.3.3 Battery Cell The ratio of cell voltage to discharging time-



5.4. Depth Of Discharge (DOD):

Depth Of Discharge (DOD) is an abbreviation that denotes the percentage of a battery's discharge in relation to its total capacity. Essentially, DOD reflects the extent to which a fully charged battery has been discharged, divided by the battery's nominal capacity. DOD is expressed as a percentage. For instance, if a 100-ampere-hour battery is discharged at a rate of 50 amperes for 20 minutes, its DOD would be calculated as 50 * 20 / 60 / 100 = 16.7%.

DOD is inversely related to battery charge, meaning it decreases as the battery's charge level increases. Battery charge is typically represented as a percentage. For example, 0% signifies that the battery is completely empty, while 100% indicates it's fully charged. In a similar manner, a DOD of 100% indicates a fully discharged battery, whereas 0% implies that the battery hasn't been discharged at all. On occasion, DOD may also be expressed in ampere-hours. For instance, in a 50-ampere-hour battery, a DOD of 0 ampere-hours indicates that the battery is fully charged, while a DOD of 50 ampere-hours means the battery is fully discharged. (W. Waag, SECONDARY BATTERIES – LEAD– ACID SYSTEMS | State-of-Charge/Health, 2009)

In certain cases, a battery's actual capacity might exceed the nominal ampere-hour rating stated on it, resulting in the calculated DOD surpassing 100%. For instance, you could reach a DOD of 55 ampere-hours for a 50-ampere-hour battery or even 110%, which exceeds its nominal rating.

In summary, batteries are designed to store energy and release it when needed. When evaluating battery efficiency, several critical factors come into play. Firstly, a battery must have the ability to store a significant amount of energy. Secondly, it should efficiently release the stored energy. This is where the depth of discharge (DOD) becomes a crucial parameter in assessing a battery's performance.

Figure 5.4.1 Single-line diagram:

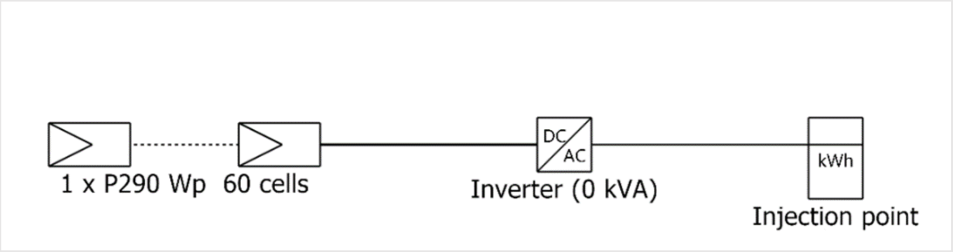
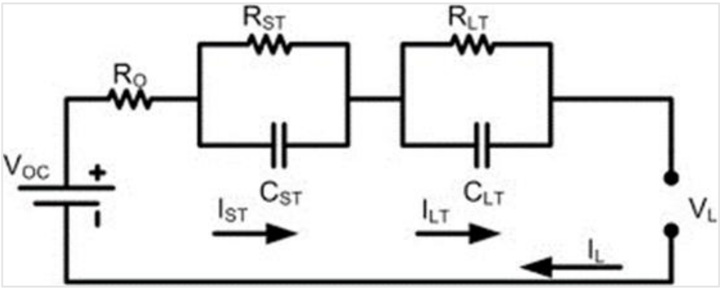


Figure 5.4.2



5.5. Battery simulation in peak:

Peak consumption hours, also known as peak demand, are the specific times during the day or night when electricity usage reaches its peak, signifying the highest levels of electricity consumption. In simple terms, these hours correspond to the moments when electricity consumption reaches its absolute maximum.

According to Statistics Denmark and the measurements we conducted over a 24-hour period, peak electricity consumption hours in Denmark are from 17:00 to 20:00

During the experiment, SEAS-NVE aimed to determine if it could encourage participants to modify their behavior by shifting a portion of their electricity consumption away from the peak period, typically between 17:00 and 20:00 (referred to as the cooking peak), to other times throughout the day.

To evaluate the effectiveness of the chosen battery for the solar system, it's essential to investigate and simulate the battery's performance during peak load periods. To achieve this, we conducted an analysis of voltage-current relationships and the charging and discharging processes by developing code in MATLAB software.

As observed in the simulations, we've designated the peak consumption hours starting at 17:00. A close analysis of the graphs reveals a simultaneous increase in voltage and current consumption during battery discharge. These simulations also illustrate the battery's adaptability to peak consumption times in terms of both type and capacity.

5.6. Calculation:

battery units = 2; Two batteries in series.

*stored energy = 26V * 180 * battery units / 1000; % Stored energy in kWh.*

initial_soc = 20 % Initial state of charge.

discharging_min_soc = 20; Minimum state of charge during discharge.

Extend the simulation time to 8 hours.

*simulation duration = 8 * 60.*

Define the two specific periods when energy demand occurs.

*period1_start = 11 * 60.*

*period1_end = 14.5 * 60.*

*period2_start = 17 * 60.*

*period2_end = 21 * 60.*

The energy demand period uses energy from the battery.

*demand = 5 * 60; % Convert 5 kWh to Wh.*

charge power = min (solar radiation, demand) / battery units.

discharge power = min (demand - solar radiation, demand) / battery units.

Figure 5.6.1 Battery Voltage, Current,Discharge Power Profile

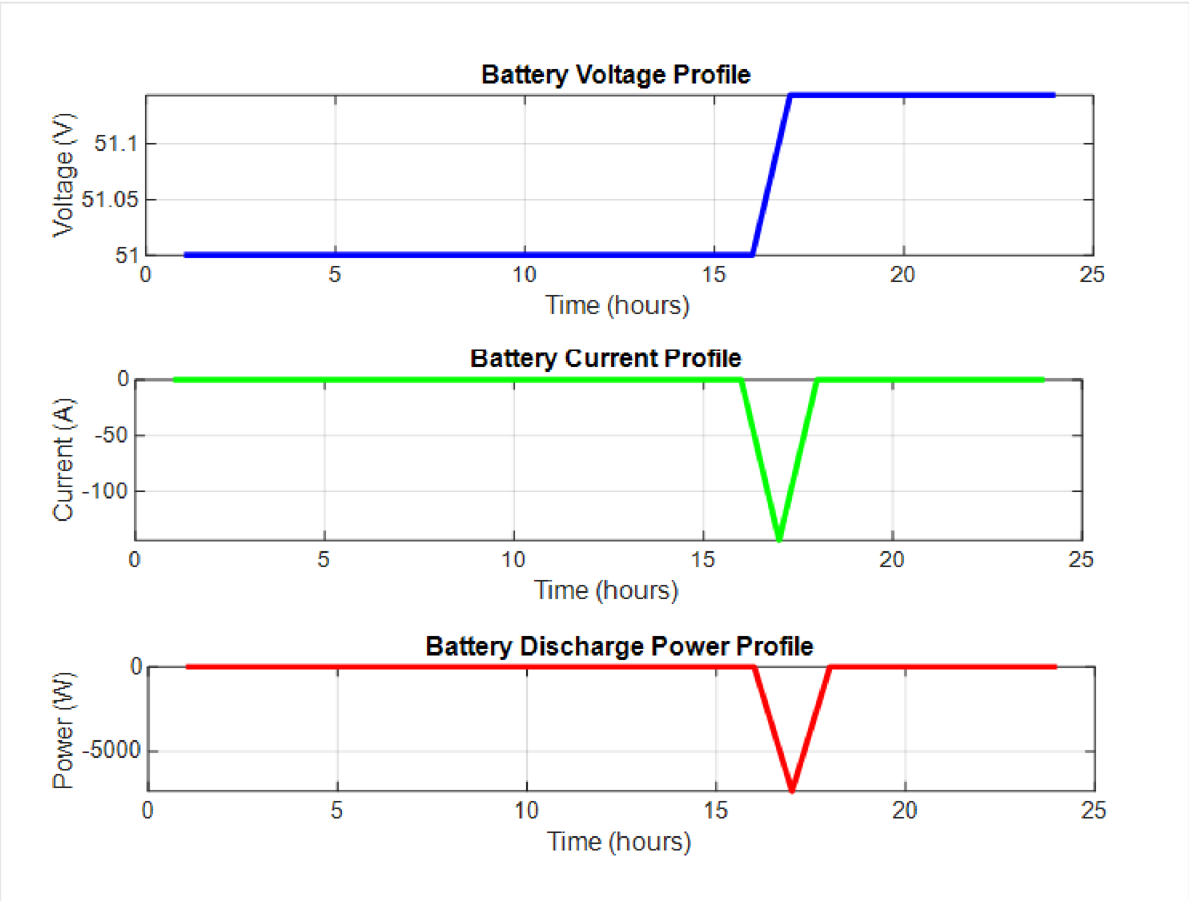


Figure 5.6.2 Battery.simulation with MATLAB.

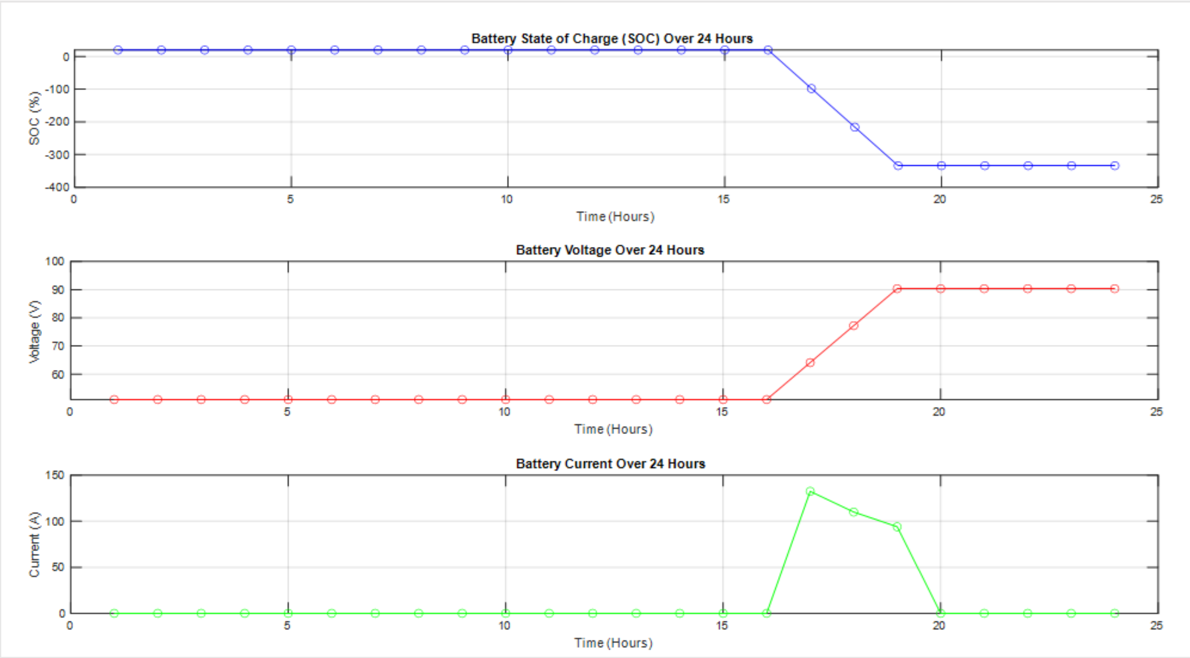


Figure 5.6.3 Batter

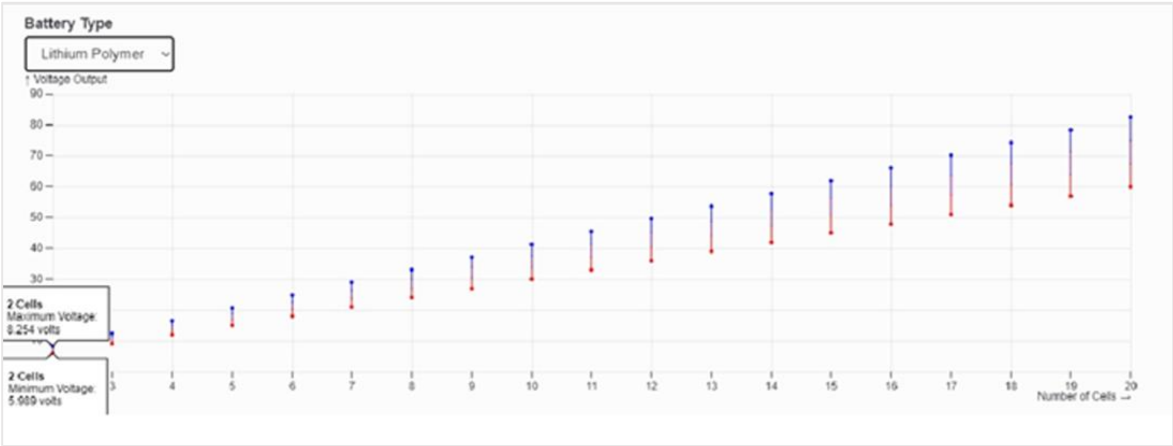
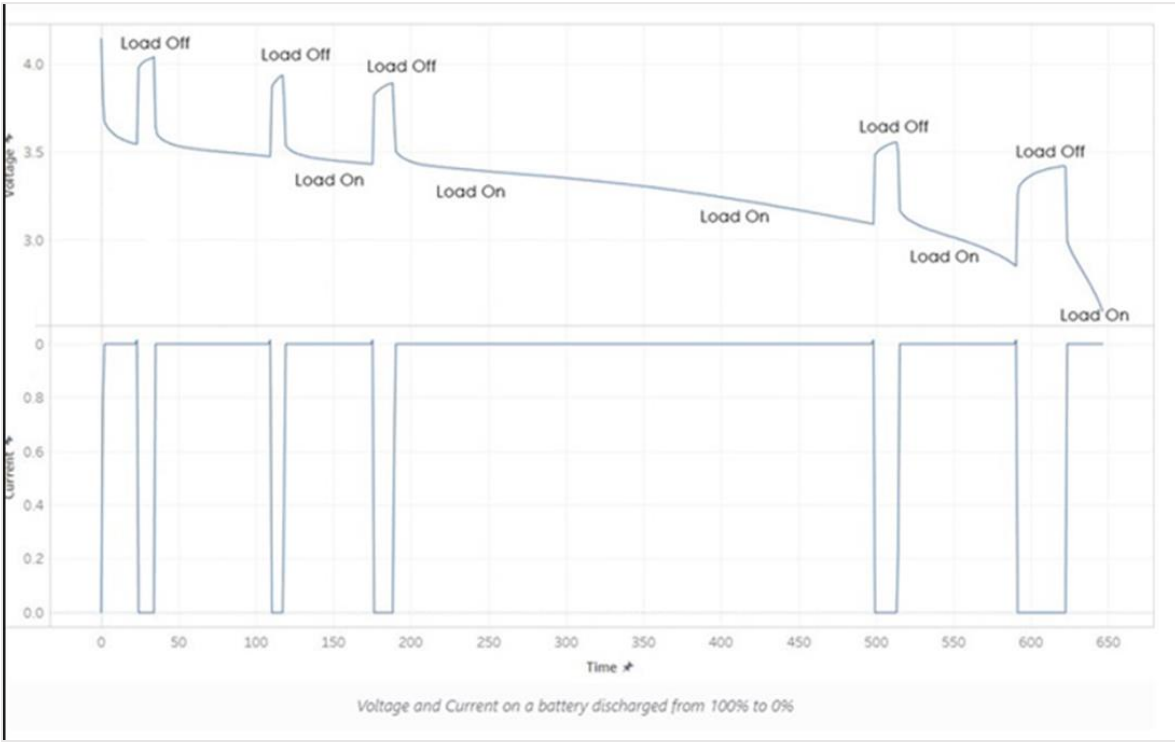


Figure 5.6.4 Load



(https://rotoye.com/modelling-the-behavior-of-a-battery/, 2023)

5.7. The batteries connected to grid:

In this section, by simulating the connection of two lithium batteries, each with 26 volts and 180 ampere-hours, which has been done in series, and by considering the tracking of the maximum voltage with the tracking of the highest solar irradiance received, the results are shown below.

Figure 5.7.1 grid connected to battery.

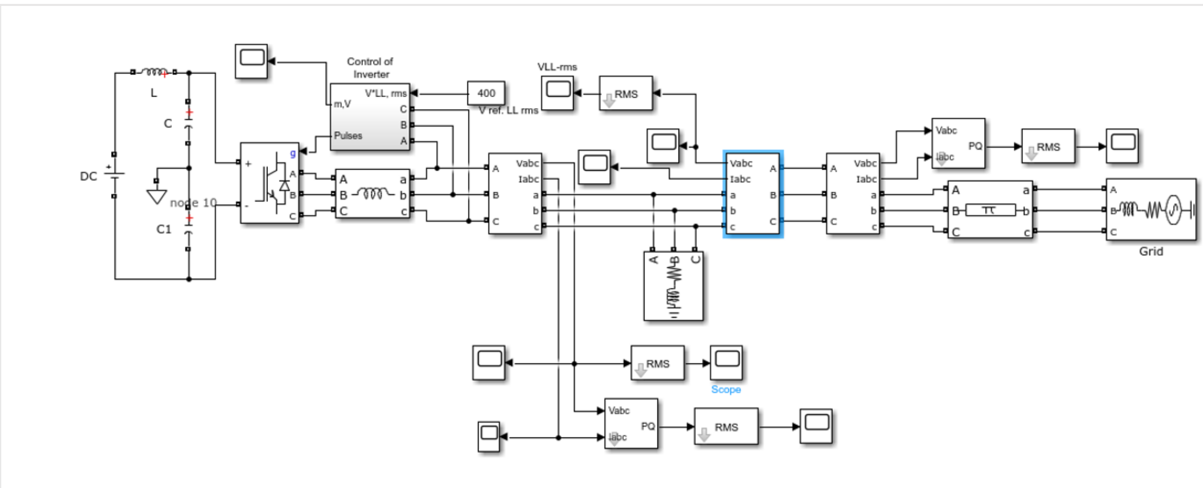


Figure 5.7.2 control of inverter model IQ7-60-x-INT

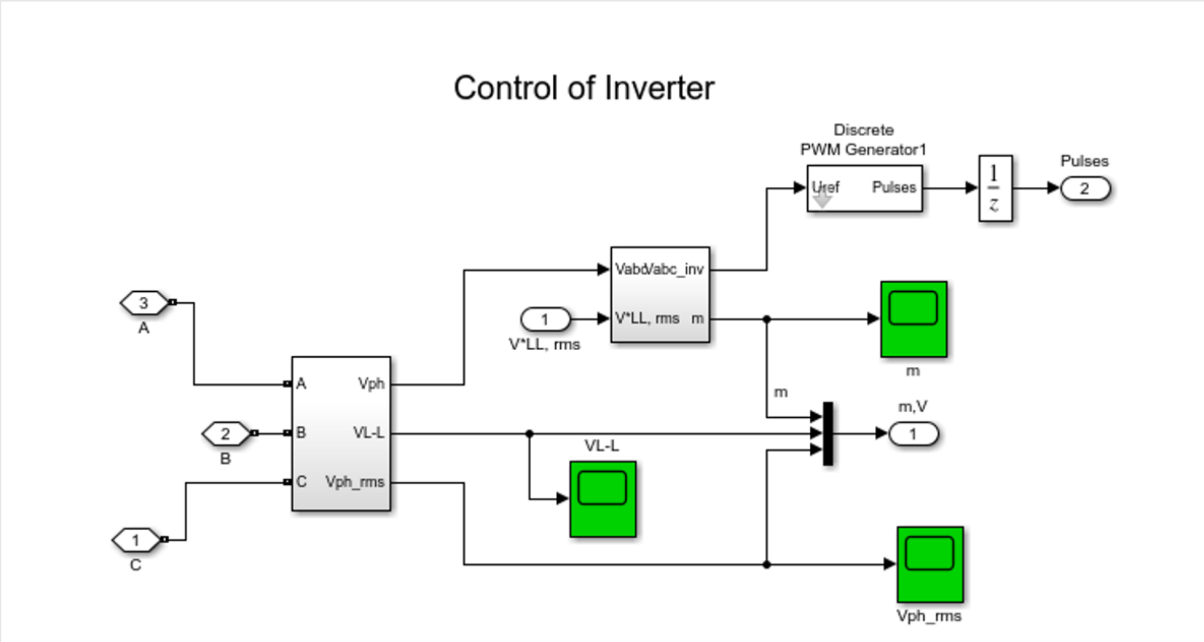


Figure 5.7.3 battery connected to grid. 3 phase 400V. I- V characters

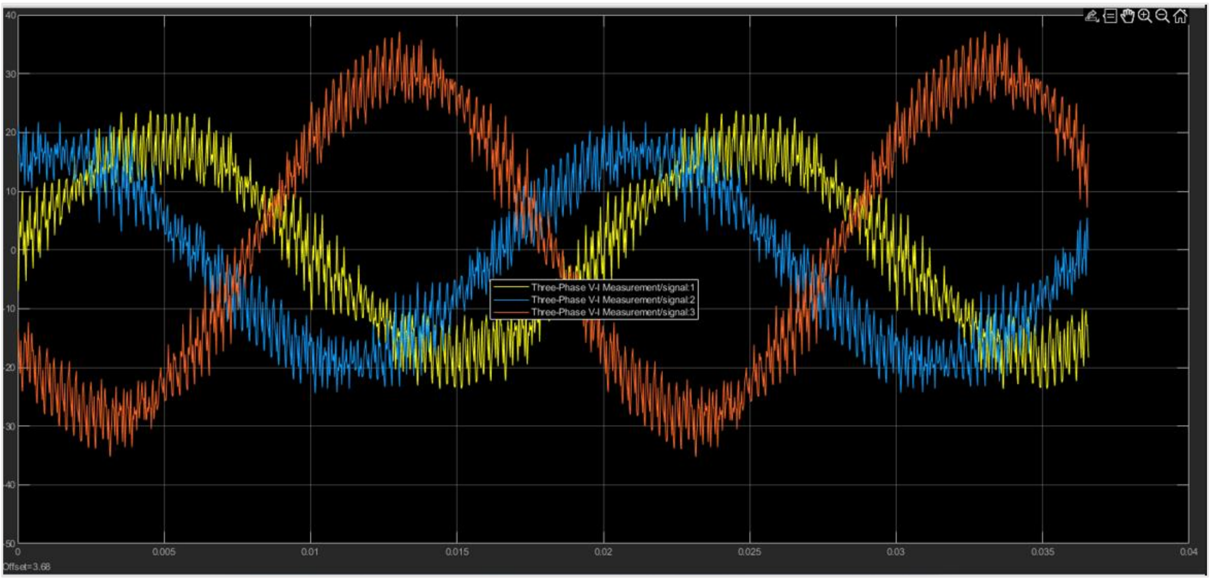


Figure 5.7.4 RMS.1 AND RMS.2. battery connected to grid. result of scope 4.

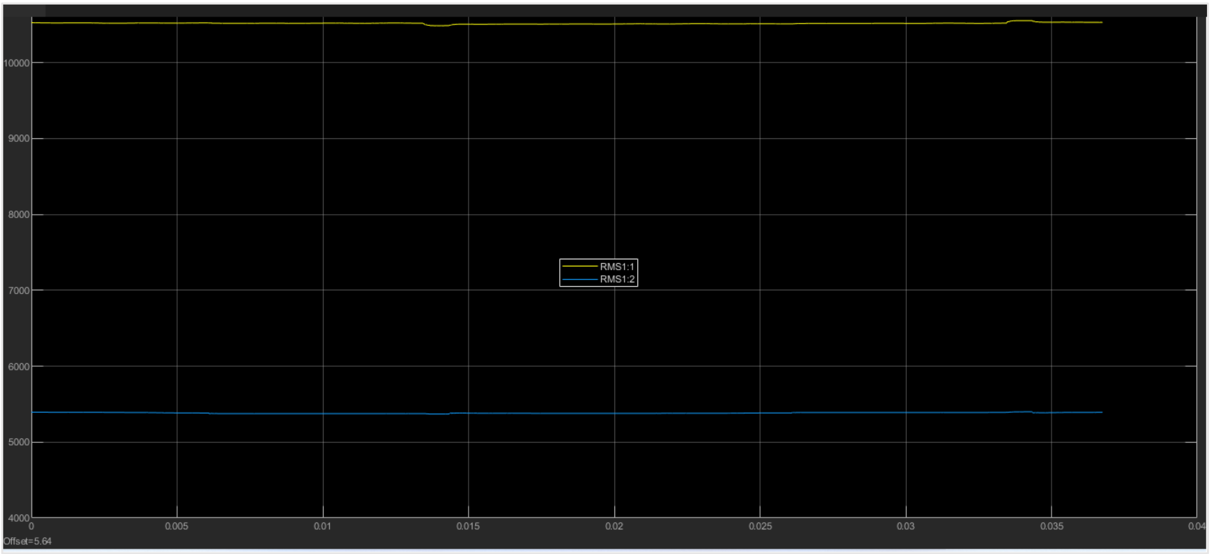
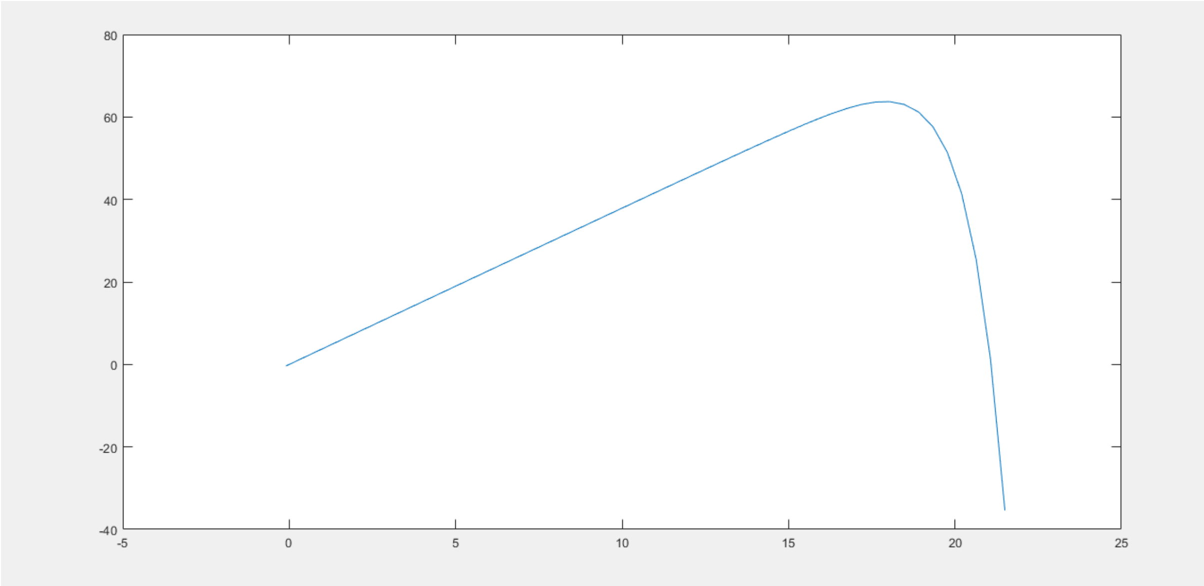


Figure 5.7.5 find MMPT for the inverter and battery scenario 5.



Chapter 6 ECONOMY:

6.1. Benfedts of the PV:

The economic benefits of the PV system are:

1. Rapid Return on Investment.
2. Enhanced Property Value with Solar Panels.
3. Protection Against Unpredictable Utility Rate Increases.
4. Job Creation and Local Economic Growth in the Solar Industry.
5. Around-the-Clock Utilization of Solar Energy.

In our economic analysis of the PV study, given the well-defined and similar equipment quantities and connection methods, the equipment's cost, and type yield only a slightly varying price range. However, key factors in the economic assessment of the solar system extend beyond equipment acquisition. These factors encompass considerations such as inflation rates, the defined lifespan of batteries or inverters, equipment, and system longevity, return on investment, and government incentives. The Aalborg Kommune is committed to increasing solar cell production, a goal delineated and emphasized in overarching policies. Solar energy in the Aalborg Kommune, around 900 m2 of photovoltaic systems were installed in 2007 with a total annual electricity generation of approx. 80 MWh.

Aalborg Kommune's Sustainability Strategy 2008-2011 contains a target that at least 5,000 m2 of solar cells must be installed by 2020. However, National legislation may make it difficult to achieve this objective. Solar cells are not yet completely commercially competitive in our latitudes, although in recent years the performance/price ratio of solar cells has developed in a favorable direction. However, continued research and development of solar cells is expected to make solar cells competitive in Denmark as well. Electricity generation from PV plants is expected to amount to around 9 GWh by 2030.[1]

Subsidies granted to large private companies have played a pivotal role in motivating these entities to invest in renewable energy, particularly solar systems. In this segment of our economic analysis, we have utilized scenario number 5, featuring two batteries connected in series, as our foundation. We have incorporated equipment pricing and technical aspects, which include design and engineering estimations, installation, and subsidies, into our calculations to provide a comprehensive overview of costs and return on investment. In the subsequent section, we have concentrated on quantifying the magnitude of carbon dioxide emissions reduction during production.

However, due to a lack of detailed knowledge about the building design and the final strategy not yet being chosen by project stakeholders, we are excused from overestimating the final costs. It's important to note that any estimates provided here may change during the final installation of the system.

We will consider an alternative strategy while maintaining the original battery selection to address this. This approach includes two options: supplying the consumer's needs during peak consumption or peak load in the main grid or supplying all the consumer's consumption in one day.

To estimate the costs, we have documented consumption information from the NRGI company based on the available data for April 2023. However, it's important to note that this cost estimate only covers the main parts of the system, and some factors have not been taken into consideration.

Based on the information we have from the NRGI company, this family consumed about 210 kilowatt hours of electricity in April 2023 and paid a fee equal to 423 Danish kroner. On the other hand, the average consumption for this family during the peak time is 1 kilowatt and the total consumption of a day is about 6400 watts or equivalent to 6.4 kilowatt hours. On the other hand, the total annual consumption of this household in 2023 was equal to 2929 kilowatt hours. Therefore, based on this information, we calculate the cost estimate as well as the return-on-investment time, as well as the production cost of each kilowatt hour of electricity from the system.

Before calculating, we will give a schematic view of how to connect the cells and equipment below, and then we will estimate the costs for both cases.

6.2 Cost estimation based on consumption at the time of peak consumption or peak load.

the amount of consumption within one day is 6400 watts, which considers the coefficient of losses, we have:

[1] Energistrategi for Aalborg Kommune frem til 2030(Maj 2011).

(6400*1.3=8320 wat

Calculate the number of panels:

The number of panels depends on the gender and efficiency of the panel production and weather conditions. To this end, we divide the amount of power required by the sun's radiation coefficient in the same area and the coefficient of the disappearance of 1.2 to specify the watt that should be produced by the panels, then round the answer to the integer. The minimum number of panels to be used is obviously that the number of panels will be useful for extending the useful life of the battery and system performance.

Pm (nominal peak power) =400W.

Vmp (maximum power voltage) = 38,6 V.

Imp (maximum power current) = 10,36 A.

Voc = 46,4 V.

Ish = 10,97 A.

So, we have:

8320/ (0.9*4) =2311 WP.

The number of panels will be obtained by dividing the number obtained by the power panel power.

6301 wp/400 V 5,75, so we need 6 panels.

Table 45 List of price for peak

Name of equipment	number	price
panel	6	2800 KR
Invertor (290 wp)	1	2000KR
Battery(180ah)	1	2000 KR
wiring	1	2000 KR
Combiner box	1	800 KR
installation	1	9000 KR
Grid connection	1	1300 KR
SUM	-	19900 KR

A 2-kW system would completely offset your energy usage.

(Total System Cost – Value of Incentives) ÷ Cost of Electricity ÷ Annual Electricity Usage = Payback Period.

So, we have:

19900-0/2.1- 2929=6.7 year

The Levelized Cost of Electricity (LCOE) is a measure that helps determine the per-unit cost of generating electricity over the lifetime of a power plant. For a photovoltaic (PV) system, you can calculate the LCOE using the following formula:

LCOE=TOTAL PRESENT COST (tpc)/total energy output over system life.

Based on scenario 4 we have: system production is 333 KWH/year (for 6 panel is =1998 kwh /year) and system life is 20 years.

So:

1990/6660=0.04 kr for each kwh.

6.3 Cost estimation based on daily household consumption.

Table 46. List of price of daily household consumption.

Name of equipment	number	price
panel	6	3000 KR
Invertor(9kwh)	1	13000KR
Battery (7 kwh)	1	40000 KR
wiring	1	3000 KR
Combiner box	1	800 KR
installation	1	9000 KR
Grid connection	1	1300 KR
SUM	-	70100KR

So: 70100/2629.9=26.5 years.

And:

LCOE=TOTAL PRESENT COST (tpc)/total energy output over system life.

Based on scenario 4 we have: system production is 333 KWH/year and system life is 20 years.

So:

70100/6660=1.7 kr for each kwh.

6.4. Cumulative cash flow:

Cash Flow:

Cash flow encompasses all incoming and outgoing monetary transactions associated with an investment project, whether industrial, service-oriented, commercial, etc., that directly impact the project's liquidity.

The project's cash flow table presents a comprehensive view of all incoming and outgoing amounts, along with net cash flows (incoming cash flows of the financial period minus outgoing cash flows of the same period) within a specified timeframe. This information is utilized in the calculation of financial indicators such as NPV, IRR, PI, etc., and forms the headings of the cash flow statement.

In most countries worldwide, the cash flow statement is typically categorized into three main sections:

Cash Flow from Operating Activities: Encompasses cash inflows and outflows resulting from internal company activities, such as revenue from the sale of goods or services and payments to employees.

Cash Flow Resulting from Investment Activities: Involves cash movements associated with the company's fixed investments, including the acquisition or sale of fixed assets and the creation of long-term bank deposits.

Cash Flow from Financial Activities: Encompasses cash transactions arising from the company's financial activities, such as issuing shares, paying dividends, receiving, or repaying facilities, etc.

Cumulative Cash Flow Analysis:

Cumulative cash flow analysis, also known as a cumulative cash flow statement, is a financial analysis method that involves tracking and summarizing the cash flows of a business or project at a specific point in time. It aids in evaluating the net effect of cash inflows and outflows over time, proving useful in financial planning, budgeting, and investment decision-making.

Key Aspects of Cumulative Cash Flow Analysis:

Cash Flows: These include both incoming and outgoing funds related to the project. Inflows generally represent revenues, investments, loans, or any other source of cash, while outflows encompass expenses, operating costs, loan repayments, and other expenditures.

Time Period: Cumulative cash flow analysis is conducted over a defined time, whether it be a month, three months, a year, or the entire duration of the project or business.

Calculation: The calculation involves starting with an initial cash balance (typically zero) and then adding or subtracting cash flows over time. The result at any given point represents the cumulative cash flow up to that moment.

Interpretation: A positive cumulative cash flow indicates that more cash has flowed in than out during the specified period, signifying financial liquidity and the ability to cover expenses and invest in growth. Conversely, a negative cumulative cash flow suggests that more cash is being spent than received, raising concerns about liquidity and financial stability.

Value of Cumulative Cash Flow Analysis:

Financial Planning: Assists individuals and businesses in planning for future cash needs, ensuring funds are available when required.

Investment Decision Making: Investors employ cumulative cash flow analysis to assess the financial health of potential investments and predict their potential for positive returns.

Budgeting: Provides insights into how cash flows in and out of the company, aiding in the creation of budgets.

Project Evaluation: Used to evaluate the profitability and financial viability of projects, such as new product launches or capital investments.

Risk Assessment: Identifies periods of financial vulnerability when cash flows are negative, enabling proactive risk management.

Chapter 7 CO2 EMISSION:

7.1. The role of PV in decreasing CO2:

Solar cells play an important role in reducing the production and emission of carbon dioxide (CO_2) and this effect is caused by different factors, including:

Zero CO_2 emissions:

Solar cells produce electricity from solar energy, so they do not return any carbon dioxide to the environment and are not a destructive factor.

Reducing dependence on fossil fuels:

The exploitation and development of the industry using solar cells in electricity production reduces the dependence on older sources such as fossil fuels. As a result, with the gradual elimination of fossil fuel power plants and the reduction of fuel consumption, more carbon dioxide is removed from the production cycle.

Renewable and sustainable energies:

Solar cells use renewable resources to generate electricity and eliminate the need to exploit fossil resources. In the long term, this sustainable approach not only reduces carbon dioxide emissions, but also ensures a continuous and sustainable energy source.

Job creation and local economic growth:

The increase in demand to produce solar cells has led to the growth of the market and job opportunities. The development of the solar cell industry will help eliminate fossil fuel-based power plants and reduce carbon emissions from production.

Additionally, photovoltaic technology offers a secure electricity source with numerous advantages over current generation methods:

Abundance of Solar Energy:

Solar energy, as the most abundant renewable source, eliminates concerns related to fossil fuels and nuclear energy.

High Safety Factor:

Photovoltaic systems typically boast a very high safety factor.

Universal Application:

Photovoltaic electricity can be generated globally, catering to diverse climates and geographical locations.

Environmental Friendliness:

Photovoltaic cells, devoid of fuel reliance, eliminate pollution associated with fossil and nuclear fuels, establishing them as the cleanest and healthiest energy source.

Modular Expansion:

The modular nature of photovoltaic technology facilitates easy and economical expansion from milliwatts to megawatts.

Efficiency and Scale:

Photovoltaic cells produce substantial power, with the technology scalable to large sizes. For instance, the world's largest photovoltaic network in Italy generates about 3.3 megawatts.

Minimal Material Usage:

Photovoltaic cells' efficient use of materials contributes to ease of manufacturing.

No Moving Parts:

Photovoltaic cells and modules lack moving parts, eliminating friction-related losses.

Zero Waste Generation:

Photovoltaic cells produce no waste, and the materials used are safe, non-toxic, and radiation-free.

Silent Operation:

Operating silently, photovoltaic cells contribute to a noise-pollution-free environment.

Cooling Not Required:

Unlike devices operating at high temperatures, photovoltaic cells do not require cooling water.

High Reliability and Ease of Use:

Highly reliable and easy to install, photovoltaic cells often do not require additional equipment or follow-up services when correctly installed.

Long Lifespan:

Commercial solar cells typically carry a 25-year warranty, attesting to their longevity. Additional devices, like batteries, may have shorter lifespans but can be replaced or repaired.

Aesthetic Considerations:

Photovoltaic cells, with careful design, enhance the architectural beauty of building facades without compromising aesthetics.

Side panels1.Result of Scenario 5(the case study for CO2 emission)

Total: 2.8 t CO2.

7.2. ENERATED EMISSIONS

Source: detailed calculation from the table below:

Table 47. Co2 details

SYSTEM LIFECYCLE EMISSIONS DETAILS			
item	**LCE**	**QUANTITY**	**SUBTOTAL**
			(kgco2)
modules	**1713kgCO2/Kwp**	**0.29kWp**	**497**
supports	**2.57kgCO2/kg**	**10.00kg**	**25.7**
inverters	**254kgCO2/units**	**1.00unit**	**254**

Total: 70. tco2.

System production: 359.56 kwh/yr.

Grid lifecycle emissions: 385gco2/kwh

SOURCE: IEA list.

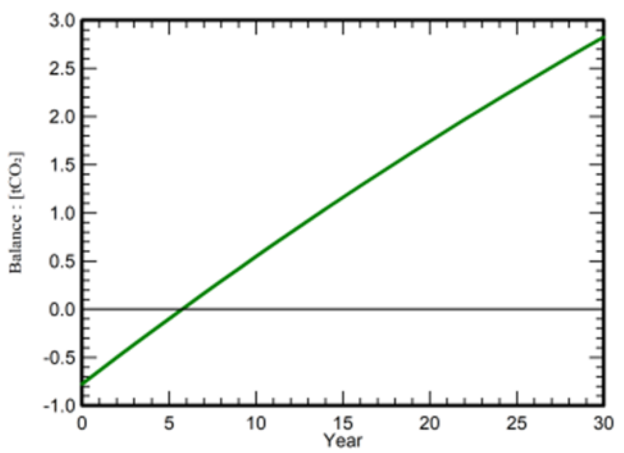
COUNTRY: DENMARK.

LIFETIME: 30 YEARS.

ANNUAL DEGRADATION: 1%.

Saved CO2 emission vs. time.

Figure 7.2.1



Chapter 8 : micro grid and smart house

Investigation of the role of smart devices and metering, and the design of a smart home system in reducing and managing consumption, and consequently reducing carbon dioxide emissions.

8.1. Introduction:

The existing networks, influenced by economic, political, and geographical factors in each country, can significantly impact the development and advancement of power networks. However, for a long time, the fundamental structure of these networks remains robust. Existing power networks, with their hierarchical structure, deliver the power generated by plants to consumers by passing through transmission and distribution networks. Fundamental issues in existing power networks include the inefficiency of the power network in managing maximum demand. The network structure, designed to control the maximum demand load corresponding to the total load considered, is often excessive. Maximum demand rarely occurs over a short period, leading to the inefficiency of the power system. Furthermore, the power network must have the ability to provide a certain surplus of electricity. This surplus is primarily the responsibility of fossil fuel power plants, resulting in lower efficiency, increased greenhouse gas production, and higher production costs. Additionally, power companies must increase their production capacity to meet the growing energy demand, necessitating the creation of more power and the delivery of it to customers through transmission lines. This capacity expansion and power plant development are accompanied by a rapidly increasing rate of fossil fuel consumption, making this development infinitely costly. On the other hand, building more power plants is not an environmentally friendly solution to meet the increasing demand for electricity. The inability of the network to create a reliable information exchange for easy troubleshooting and maintenance of expensive equipment for power companies introduces various levels for command transmission, control, and data acquisition. This includes the introduction and creation of a well-established control and data acquisition system, such as the stable and recognized supervisory control and data acquisition (SCADA) system. With limited functionality, companies controlling the upper functions of distribution networks are unable to control them in real time.

8.2. Key Characteristics of Smart Grids

main characteristics of smart grids essentially describe their capabilities. Smart grids are defined to eliminate the drawbacks of existing networks and have the following specifications:

Informed and Active Consumer Participation:

Active participation of consumers in electricity markets has tangible benefits for both the grid and electricity companies. Smart grids provide necessary information about consumption patterns and the cost of electricity to consumers, enabling them to engage in new electricity markets. Accurate information dissemination empowers consumers to adjust their consumption based on a balance between the demand local production resources and the existing power grid. The ability to reduce or shift peak load consumption allows electricity producers to lower investment and operational costs, simultaneously benefiting the environment by reducing line losses and minimizing the operational time of low-efficiency power plants.

Improvement in Production and Storage:

A smart grid has the capability to efficiently utilize large, centralized power plants as well as distributed energy resources at the consumer's location. While large power plants, including advanced nuclear power plants, continue to play a fundamental role in smart grids, numerous small, distributed energy sources such as photovoltaic cells, wind, advanced batteries, and fuel cells can be integrated into the network. Easily connecting distributed energy sources to the power grid allows for the seamless utilization of various resource types, optimizing efficiency.

These characteristics collectively enhance the overall efficiency, resilience, and environmental sustainability of the power grid, making it more adaptable to the changing demands and challenges of the modern energy landscape.

8.3. Why the smart grid is important?

Large power plants are situated in specific locations to provide power supply in traditional networks. The energy produced needs to be transmitted to consumption points via transmission and distribution networks. However, the power system is facing numerous challenges such as reduced reliability and accessibility due to aging infrastructure of the electrical system and high costs associated with energy losses during transmission to load points.

To address upcoming challenges, especially environmental concerns, the power industry is turning towards new technologies, such as distributed generation technology for electricity production. Constraints on fossil fuels and air pollution are significant motivators for the expansion of this technology. Generating electricity near the point of consumption and reducing losses in the system can provide more flexibility to offer various services to consumers.

The integration of these resources with a focus on visibility, proper communication, and efficient control can enhance the effective participation of distributed generation sources. Microgrids are active low-voltage or medium-voltage distribution networks consisting of loads, distributed generation sources, and control devices. These networks can be separated from the main network and operated as isolated islands, which address technical issues related to increasing reliability and the quality of power delivered to consumers.

In the future, multi-microgrid networks consisting of microgrids, distributed generation sources, and interruptible and non-interruptible loads will take shape. Operators of multi-microgrid networks must implement the necessary strategies for the independent operation of upstream networks. They must satisfy the resources and loads of the entire system under their control, considering all technical and economic constraints, as well as potential connections with upstream markets.

From this perspective, operators of microgrids and multi-microgrid networks are obligated to perform a set of tasks that ensure system security and satisfaction for the members of their networks. To achieve this, they must plan with the goal of optimally using resources while considering all technical and economic constraints, as well as potential connections with upstream markets. Economic incentives must be created for energy production resources so that networks with high penetration of distributed generation sources can function effectively.8.4. adjusting and levelling the demand

Demand adjustment and leveling stand out as significant advantages of the smart grid for energy distribution companies. Managing peak demand is crucial, given the higher costs and inefficiencies associated with electricity production during peak periods. The smart grid effectively addresses this challenge by mitigating sudden spikes in demand, resulting in a more stable supply-and-demand dynamic.

A key benefit is the optimization of electricity generation for distribution companies, leading to cost savings. Utilizing smart equipment and devices enables better management of supply and demand. For example, the implementation of smart home systems allows for strategic power management, such as temporarily turning off non-essential appliances during peak times.

Moreover, the adoption of smart meters and a two-way dialogue system minimizes the need for manual meter readings, significantly reducing network management costs. This streamlined process enhances the efficiency of collecting electricity consumption data, contributing to increased profits for related companies.

The implementation of time-of-use tariffs is another advantage, allowing power companies to incentivize customers to reduce consumption during peak times. This strategy not only benefits electricity suppliers financially but also encourage consumers to adopt more energy-efficient practices.

The smart grid's distribution intelligence plays a crucial role in improving power transmission efficiency. The complexity of the existing national grid and the network of cables is mitigated by processing information and employing advanced communication technologies.

Furthermore, the smart grid contributes to environmental goals by reducing carbon production and emissions. Efficient electricity generation during peak demand and the integration of renewable energy sources into the grid further minimize environmental impact.

The integration of renewable energy also reduces transmission distances, resulting in a more efficient grid with fewer transmission losses. This decentralization of electricity generation points across the country enhances grid efficiency and reliability.

Lastly, the smart grid's self-healing capabilities contribute to fast power outage detection and mitigation. Establishing alternative paths for electricity distribution minimizes the impact of outages and shortens the time required for network repairs, ultimately improving overall grid resilience.

8.5. Sing Vensim software, model and assess the impact of installing distributed generation (photovoltaic) and capacitors on electricity consumption from a dynamic systems perspective for subscribers.

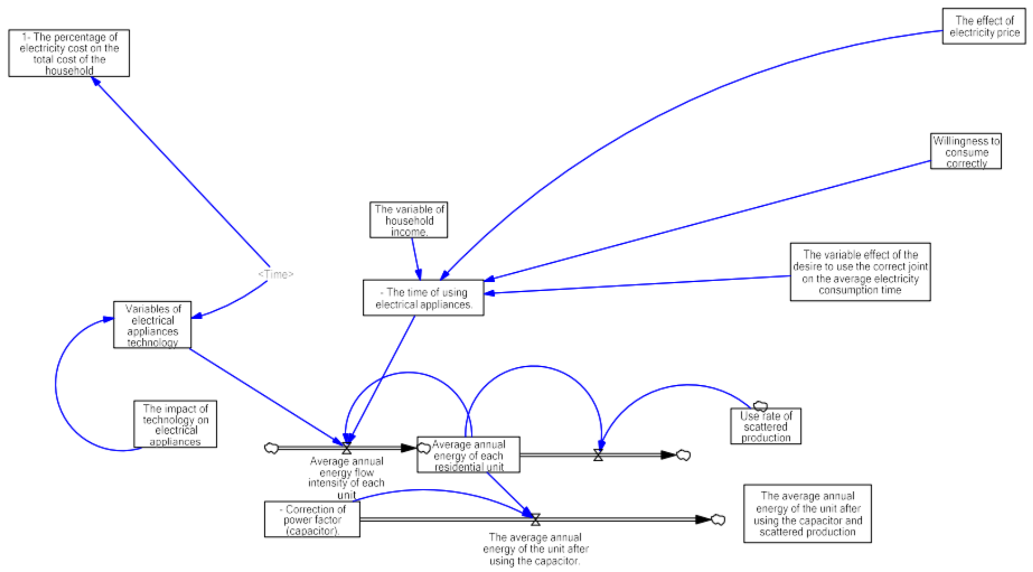
To date, no studies have explored the impact of capacitor placement on shared load consumption using System Dynamics. This method was created in the mid-1950s by Professor Forrester at MIT (https://www.anylogic.com/upload/books/new-big-book/2-three-methods-in-simulation-modeling.pdf, 2020). He transformed the paradigm of derivation in control theory into the accumulation (integration) in the system's dynamics. This was based on his belief that nature accumulates instead of differentiating.

Most economists agree that there is a strong correlation between energy consumption and economic growth. Some, such as Nair and Ayres (2000), even consider energy to be the most important factor in a country's economic growth (Stern, 2004). System dynamics focuses on feedback processes and causal relationships. It can recognize and explain the relationships between different systems. The method assumes that the system's behavior is determined based on a continuous network of feedback loops (Bay and Labk, 1996).

According to Stern (2000), the structure of the system determines its behavior.

Figure 8.5.1 illustrates the simulated heart of the flow accumulation using Vensim software. The simulation employs variables that have a significant impact on consumers' behavior. The temperature variable is a key factor that affects other variables like costs, technology, and the number of electrical appliances in the proposed model. Another vital variable for controlling the energy consumption of a commercial unit is the distributed generation variable and the power factor correction variable. The table shows external, internal, and auxiliary variables.

Figure 0.5.1. vensim model. impact of installing distributed pv and capacitors



The variables that we investigate their impact on dynamics are as follows:

1. The percentage of electricity cost on the total cost of the household.
2. The effect of electricity price.
3. The variable of household income.
4. The variable effect of the desire to use the correct joint on the average electricity consumption time.
5. The time of using electrical appliances.
6. Willingness to consume correctly.
7. Variables of electrical appliances technology.
8. The impact of technology on electrical appliances.
9. Average annual energy of each residential unit.
10. Average annual energy flow intensity of each unit.
11. Use of scattered production.
12. Use rate of scattered production.
13. Correction of power factor (capacitor).
14. The average annual energy of the unit after using the capacitor and scattered production.

Table 48. type of variables in the proposed model

Type of variables in the proposed model

Auxiliary variables	Endogenous variables	Exogenous variables
Impact of household electrical appliances. - Search variable for the percentage of electricity cost to total household expenses. - Search variable for income. - Impact of income on consumer behavior. - Impact of product prices on consumer behavior - Average annual energy consumption of residential unit after using a capacitor and distributed generation (solar cell)	- Propensity for proper consumption. - Time of using electrical appliances (reduction).	Percentage of electricity cost to the total residential unit cost. -Family income level. - Impact of electrical appliances technology Cost of using distributed generation (solar cells in this case).

After determining the variable types, and equations, and based on the estimated load of commercial units and consumption levels in the year 2022, the values of the mentioned variables have been entered into the Vensim software, and a ten-year time horizon has been forecasted for the future.

1.The use of Distributed Generation (DG) through photovoltaic systems leads to a reduction in load and the liberation of power grid capacity. By increasing investment, shared energy can be supplied using solar panels.

The distributed generation rate equivalent to 60% of the energy consumption for each commercial consumer is considered, as shown in Equation (1):

(1) Rate the use of DG=0.2 Units=Percent

The power factor correction rate in the power grid is 50%, considering the energy consumption of each consumer, as shown in the Equation Rate of the use of PF=0.60. Units=Percent (2)

The initial value of the variable is assumed to be the average annual energy consumption for a 5-year period, based on the commercial electricity tariff of the country, equivalent to 4000 kilowatt-hours. This is calculated using Equation (3):

Rate Average Annual Energy Consumption Unit home=
(((1−technology Appliunce+The incline time to use electrical appliances) +1)
×4000−Average Annual Energy Consumption unit house).

The variable value for the current state is obtained from Equation (4):

4)Average Annual Energy Consumption unit =Average Annual Energy Consumption unit house−use of DG.
units: KWh

The rate of electricity reselling is estimated based on available information from the energy ministry. The values of average income per home unit, average price per unit of home electricity, and the ratio of electricity cost to total costs are considered using references [4] and [5].

The impacts of electricity price and income on consumer behavior are considered as 0.1 and 0.4, respectively.

Chapter 9. Conclusion

9.1. conclusion:

The Green Hub Hus project represents a forward-looking paradigm for the evolution of construction and energy supply industries. It strives for green construction practices while simultaneously diversifying energy production sources, prioritizing renewable energy. The project's exploration of solar cells within the context of a smart grid underscores a crucial finding: incorporating solar energy into the energy mix, coupled with accurate storage solutions in lithium batteries, is economically and environmentally justified. The key takeaway is the need to scale up the scope and size of such projects.

The synergy between smart grid technologies and intelligent building design, particularly with the integration of a solar power plant connected to the grid and precise energy storage in lithium batteries, aligns with the project's primary goal—carbon production reduction. Localizing thermal energy and electricity production emerges as an indisputable reality.

The incorporation of solar cells, whether as integral building materials or attachments to roofs and walls, addresses critical aspects of energy production network stability, as well as the safety and comfort of residents. I recommend expanding the project's impact by incorporating a smart grid definition, encompassing other elements of green energy production, such as Combined Heat and Power (CHP).

Furthermore, advocating for the use of solar cells as an inherent part of the project's construction materials ensures a seamless integration of sustainable energy practices. Recognizing the return on investment in such projects is vital, with the added benefit of lower maintenance costs compared to outdated models. Acknowledging political developments as influential factors underscores the heightened importance of establishing green energy hubs, as demonstrated by events in the past three years.

Finally, to enhance network security, it is advisable to rely on domestic control and hardware manufacturing companies. This precaution mitigates potential vulnerabilities associated with external entities, such as Chinese companies producing solar cells.

Chapter 10. Discussion:

As the final plans for this project have not yet been completed by the architects and there is only an overview of the plan and given that we have focused solely on one of the project's objectives, it is important to note that the discussions and the tasks presented here can potentially be done. beyond or more comprehensive than the results obtained. As more information becomes available and the project progresses, further enhancements and improvements may be possible in the future. The scope of consumption can vary based on cultural and economic background. The point of view of project stakeholders regarding the choice and type of smart grid definition and economic estimates should be changed. What is clear is that investment in the discussion of energy in this project has not only an economic aspect but also an environmental aspect, and security and sustainability are the pillars of the reasons for starting this project and similar ones in Denmark.

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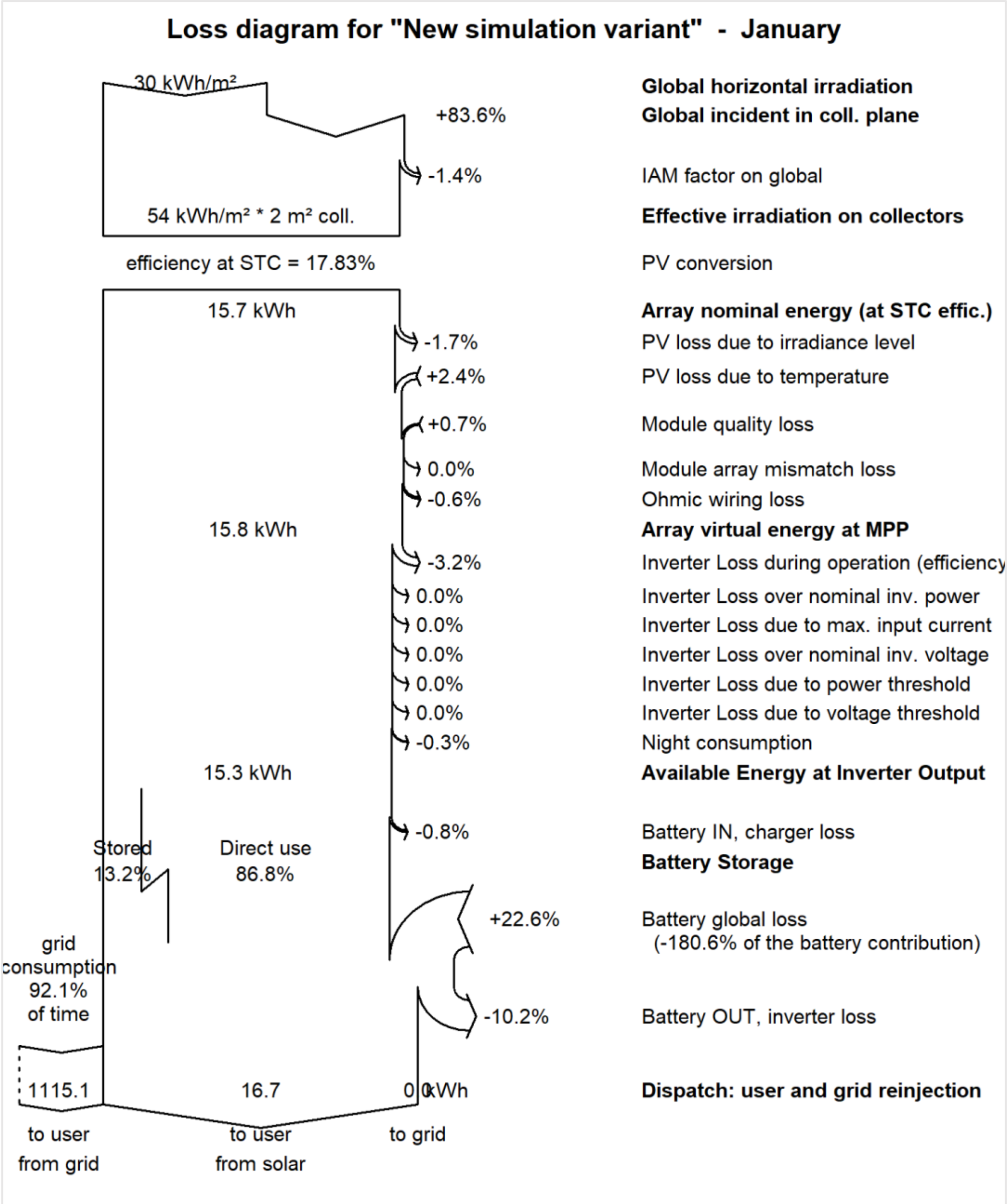
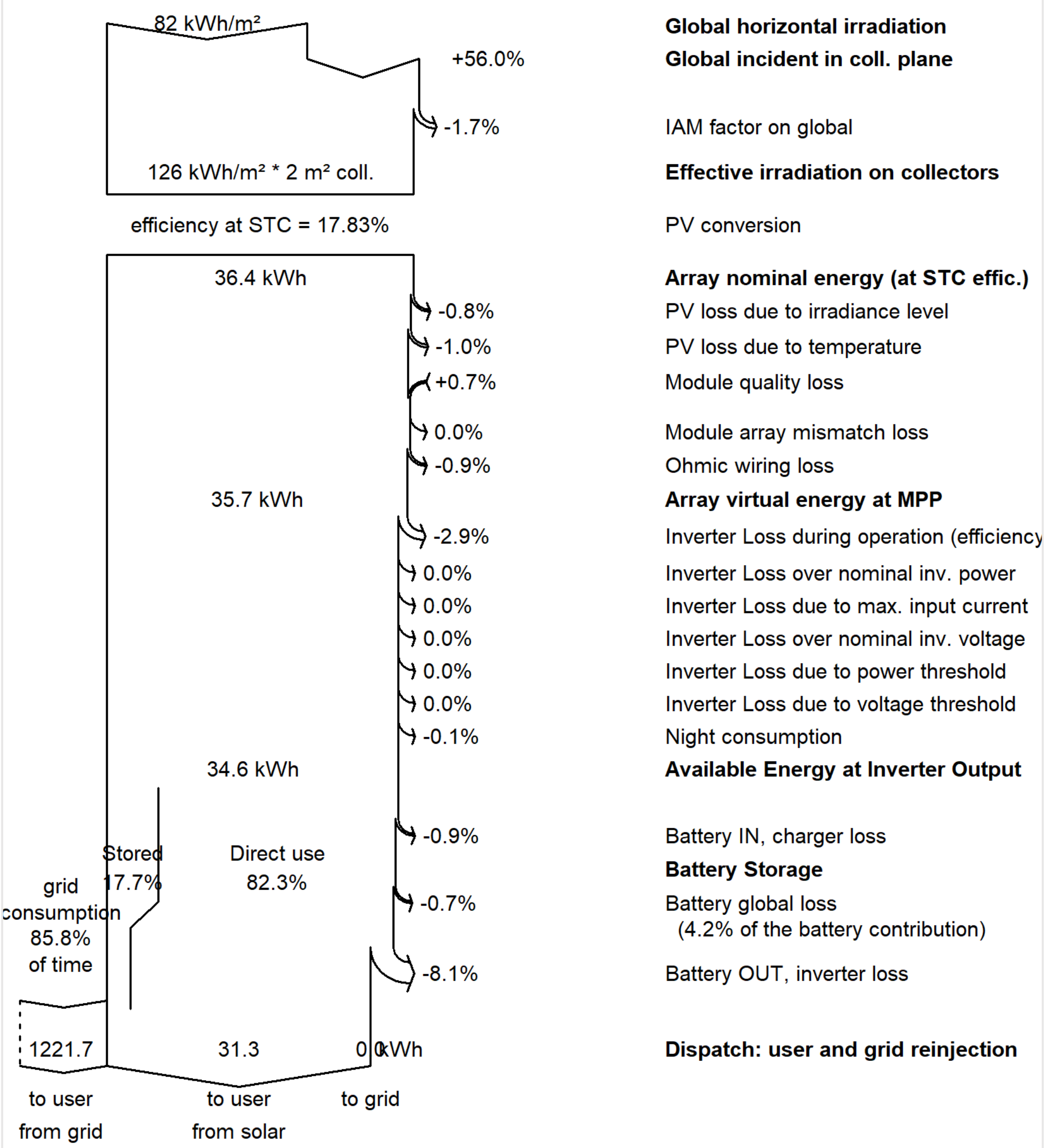
Appendix:

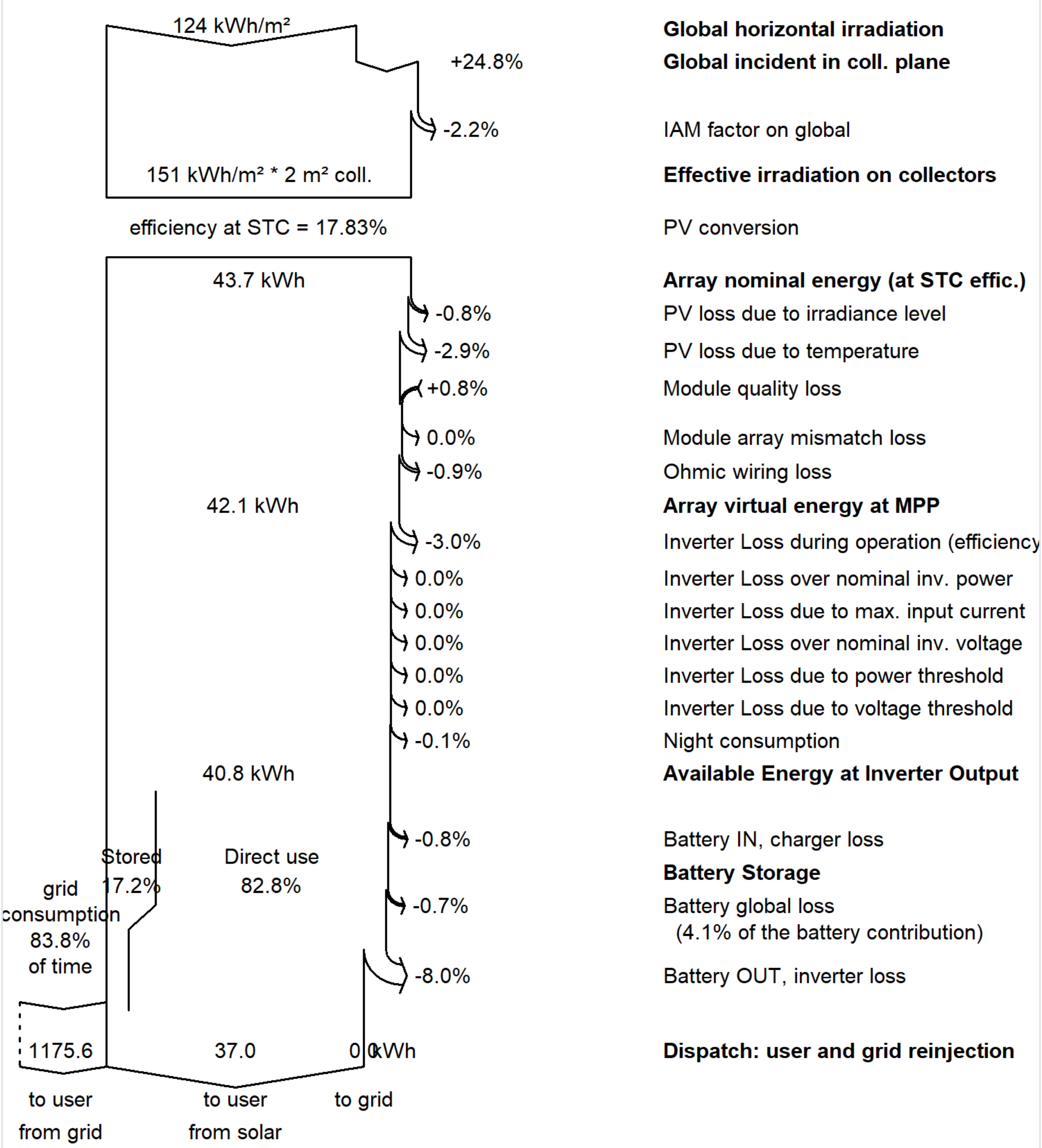


Loss diagram for "New simulation variant" - January
30 kWh/m²
+83.6%
-1.4%
54 kWh/m² * 2 m² coll.
efficiency at STC = 17.83%
15.7 kWh
-1.7%
+2.4%
+0.7%
0.0%
-0.6%
15.8 kWh
-3.2%
0.0%
0.0%
0.0%
0.0%
0.0%
-0.3%
15.3 kWh
-0.8%
Stored
13.2%
Direct use
86.8%
+22.6%
grid
consumption
92.1%
of time
-10.2%
1115.1
16.7
0.0 kWh
to user
from grid
to user
from solar
to grid
Global horizontal irradiation
Global incident in coll. plane
IAM factor on global
Effective irradiation on collectors
PV conversion
Array nominal energy (at STC effic.)
PV loss due to irradiance level
PV loss due to temperature
Module quality loss
Module array mismatch loss
Ohmic wiring loss
Array virtual energy at MPP
Inverter Loss during operation (efficiency
Inverter Loss over nominal inv. power
Inverter Loss due to max. input current
Inverter Loss over nominal inv. voltage
Inverter Loss due to power threshold
Inverter Loss due to voltage threshold
Night consumption
Available Energy at Inverter Output
Battery IN, charger loss
Battery Storage
Battery global loss
(-180.6% of the battery contribution)
Battery OUT, inverter loss
Dispatch: user and grid reinjection

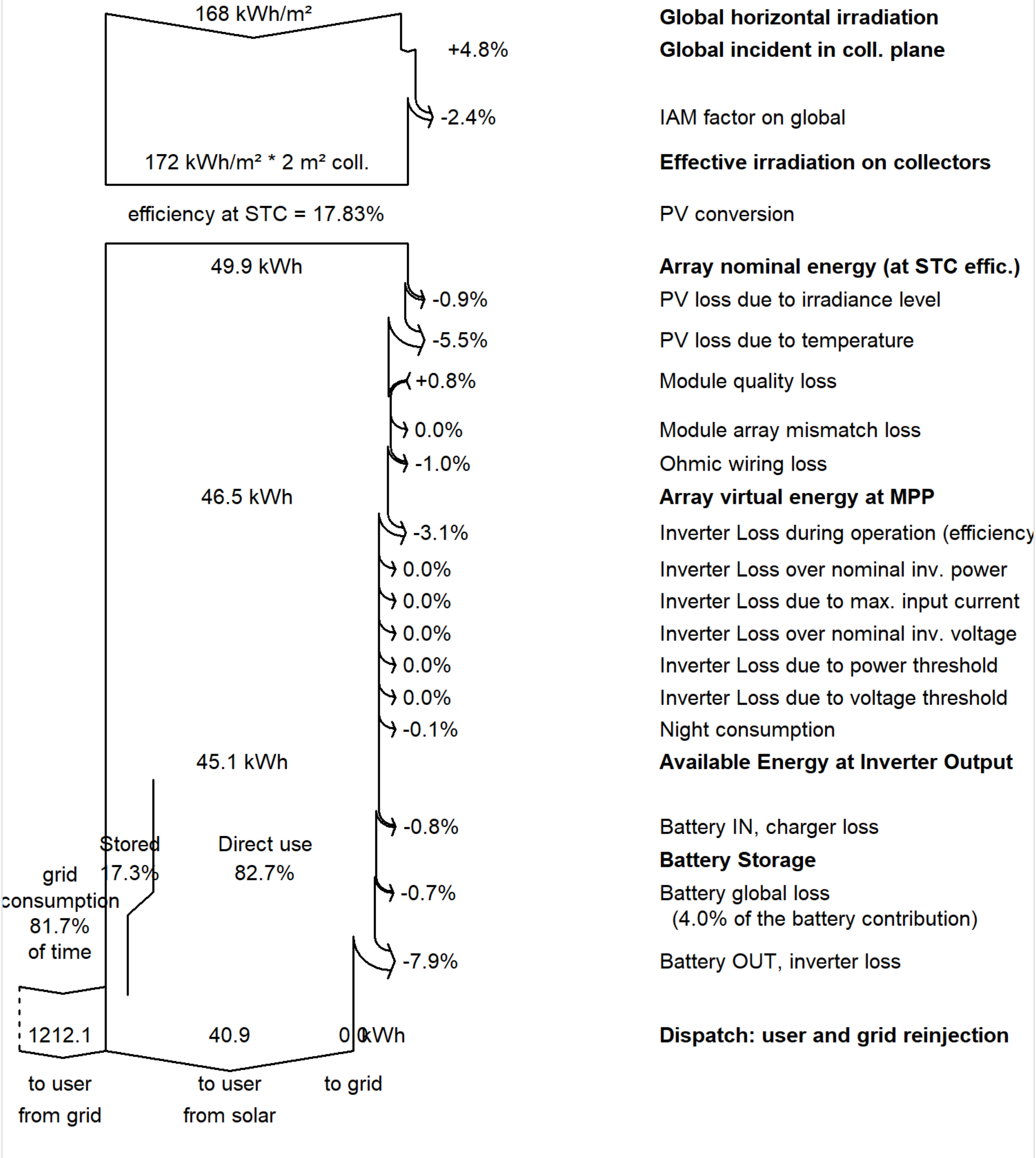
Loss diagram for "New simulation variant" - February



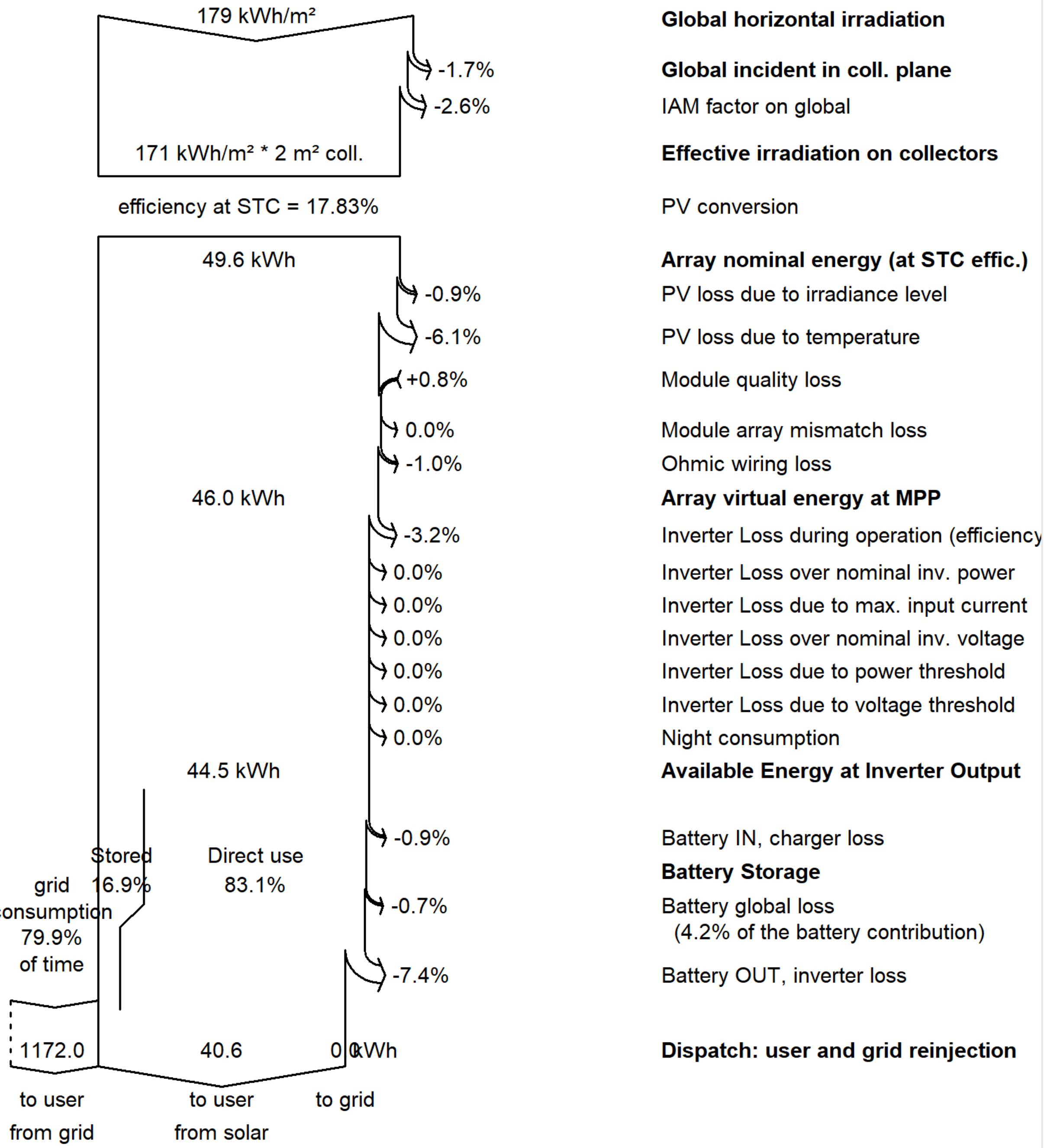
Loss diagram for "New simulation variant" - March



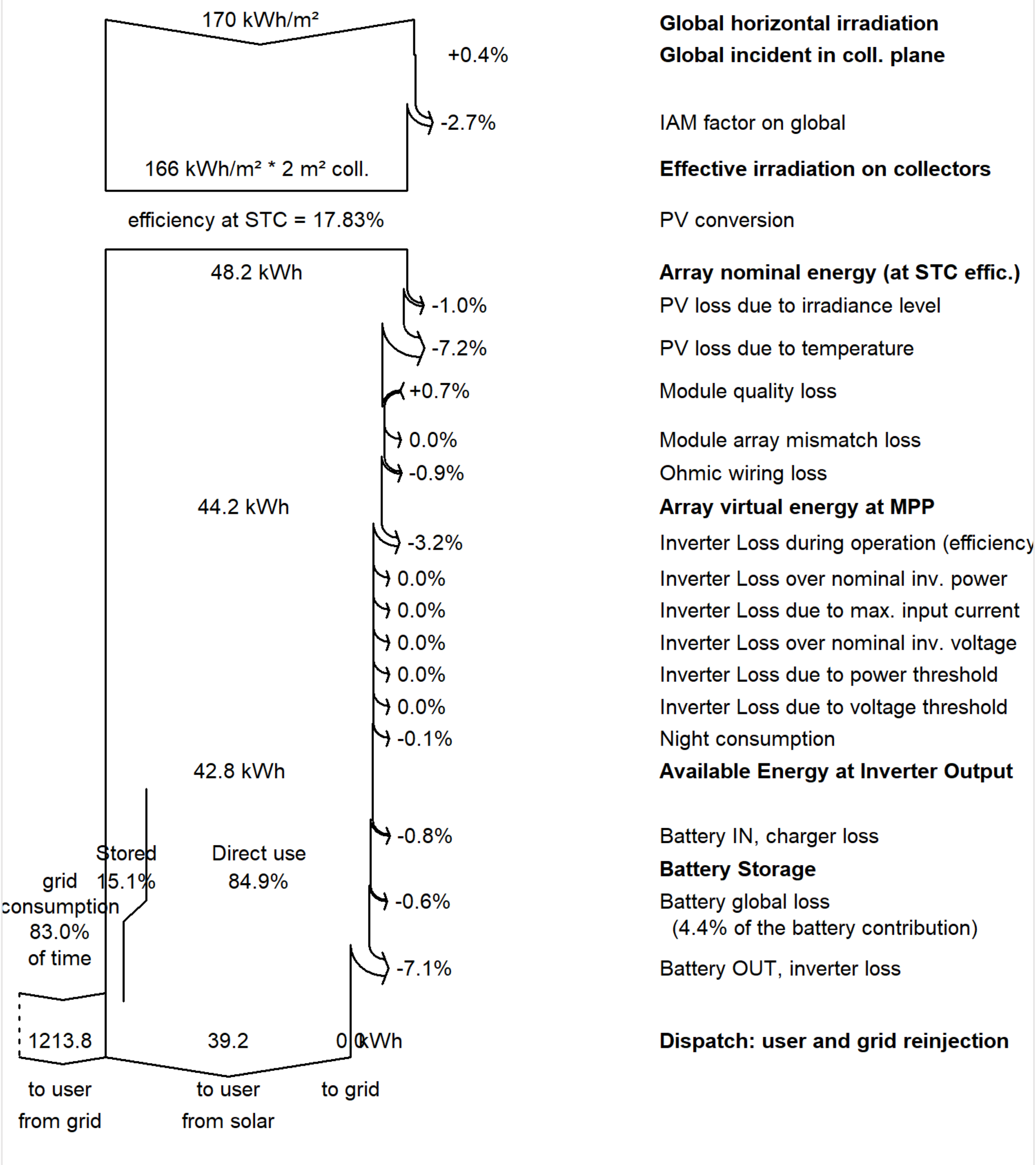
Loss diagram for "New simulation variant" - April

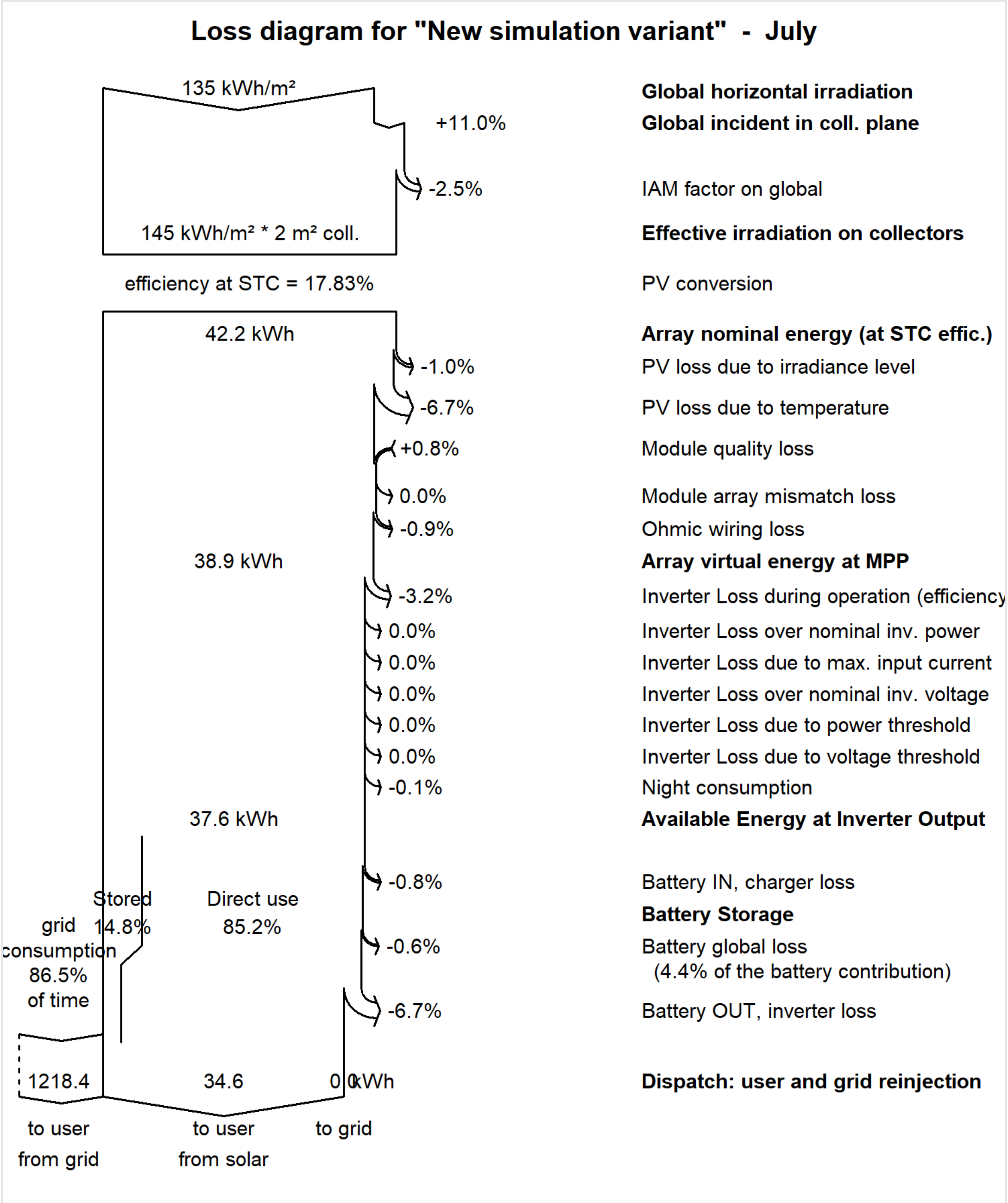


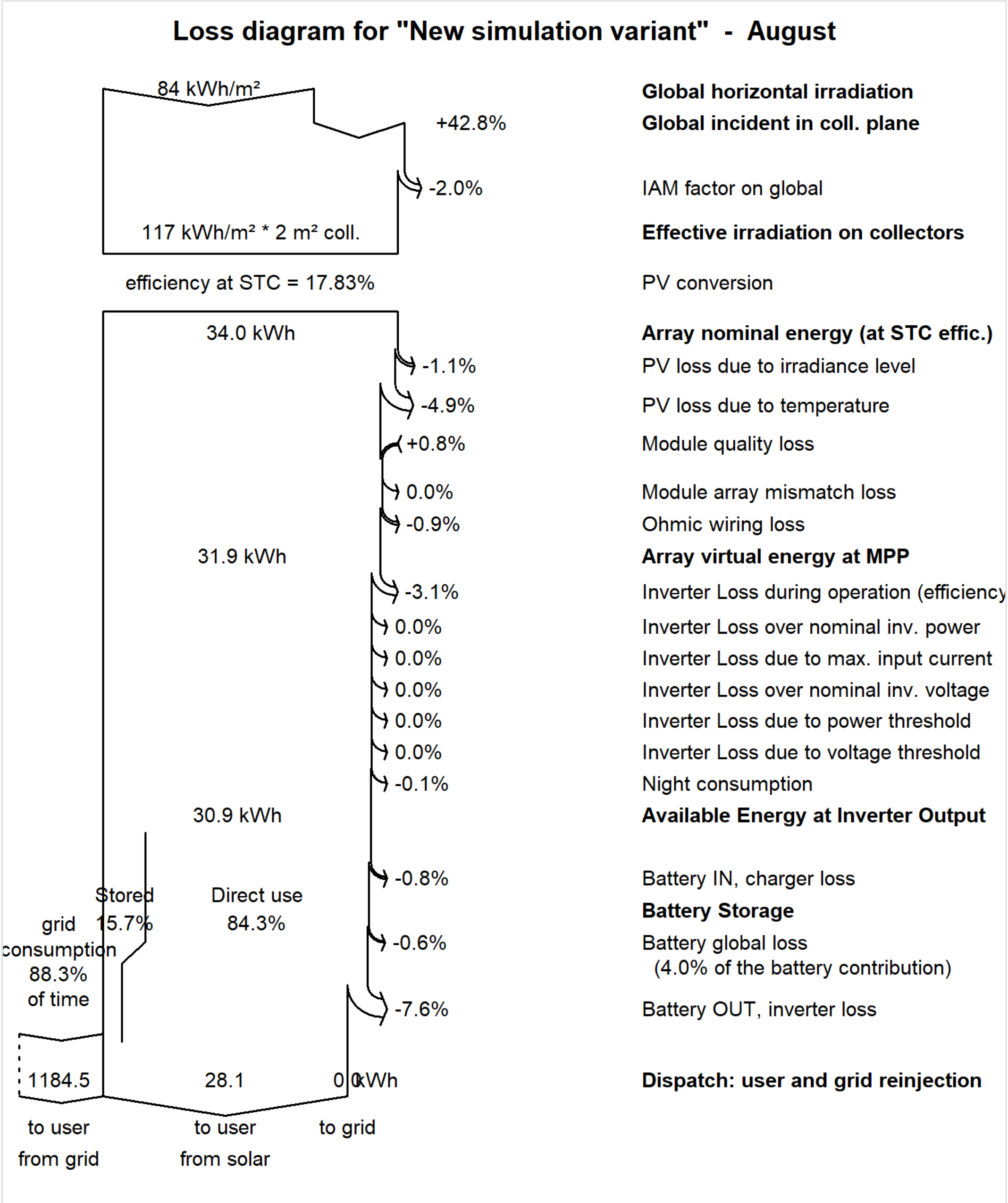
Loss diagram for "New simulation variant" - May

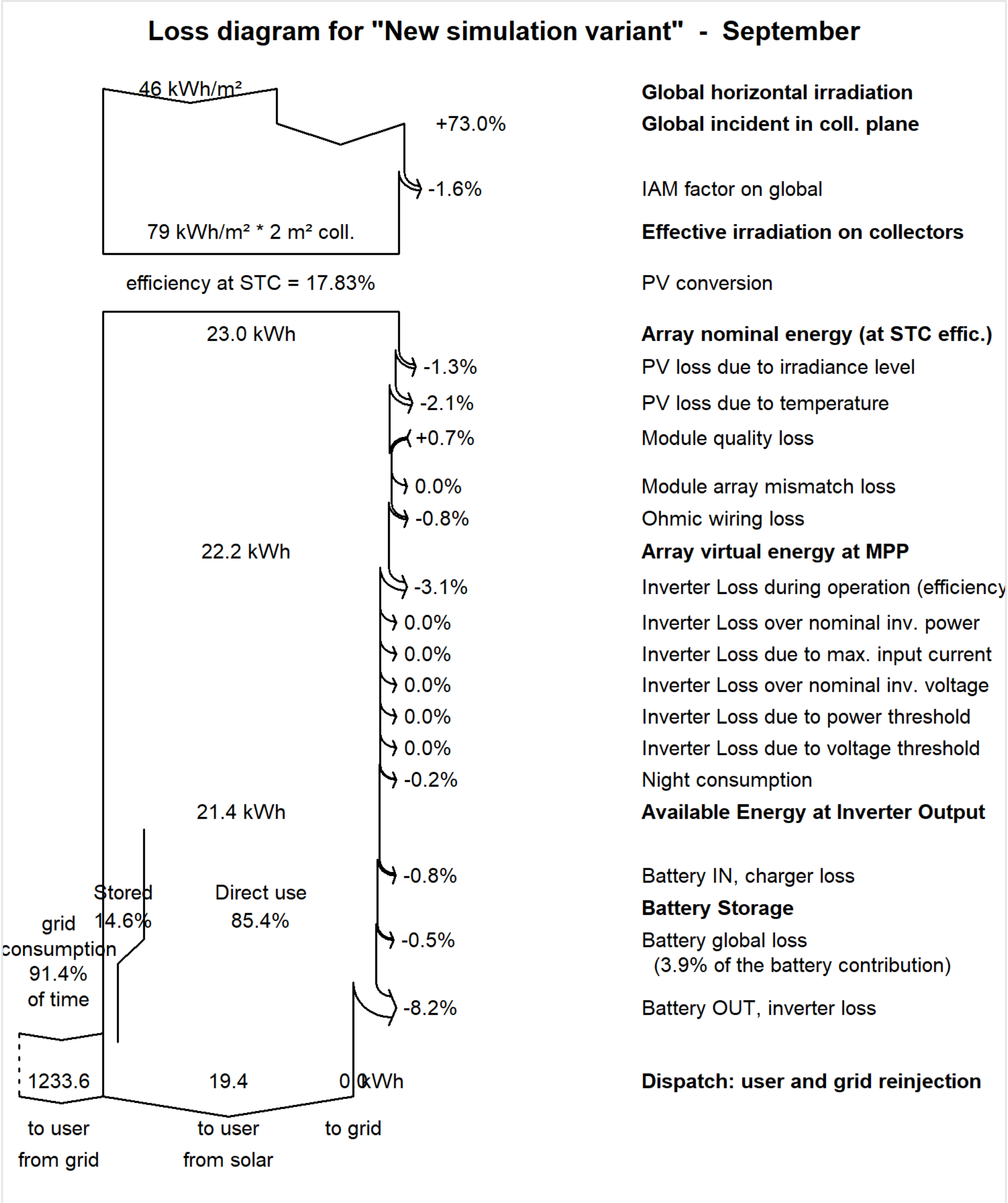


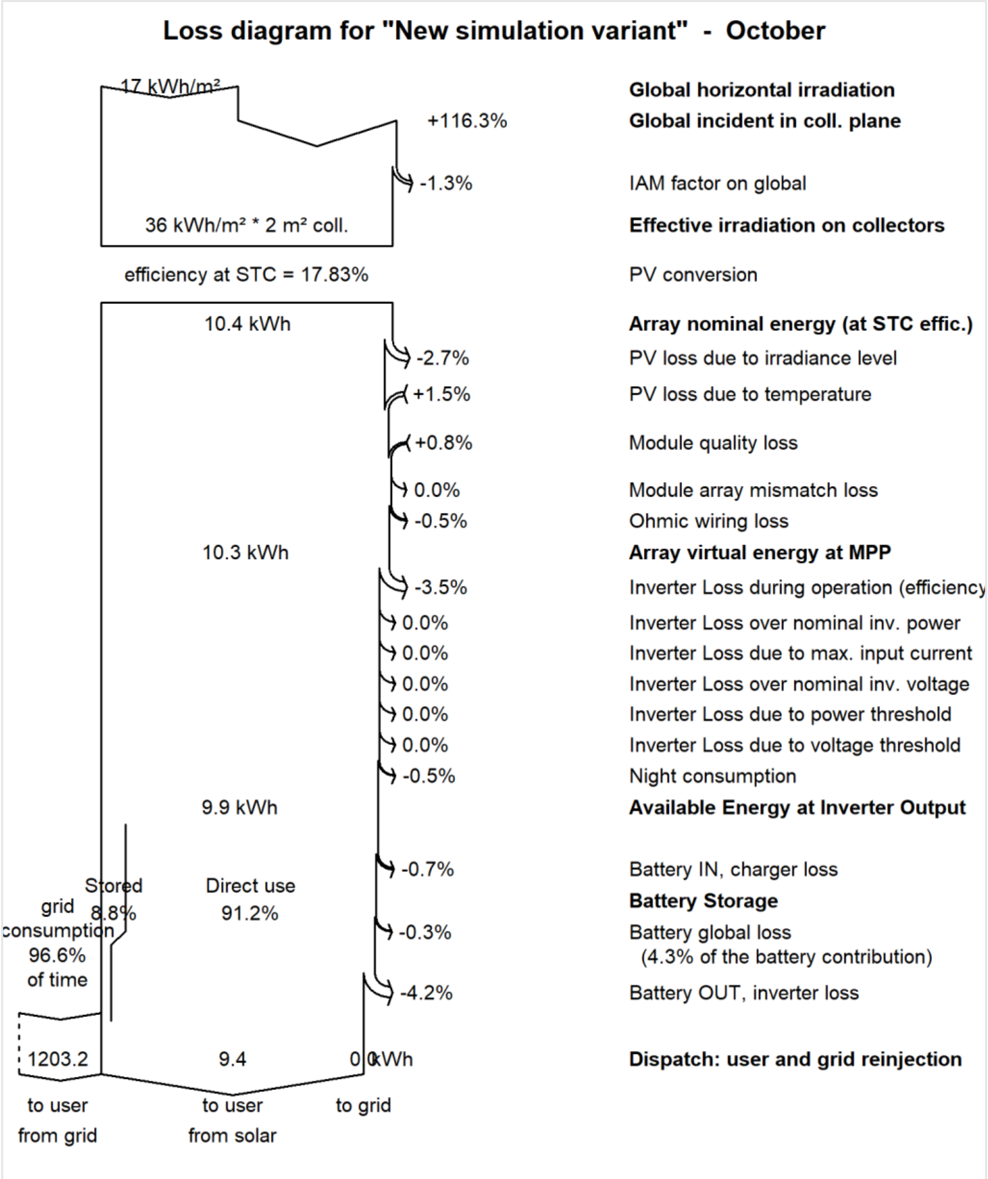
Loss diagram for "New simulation variant" - June



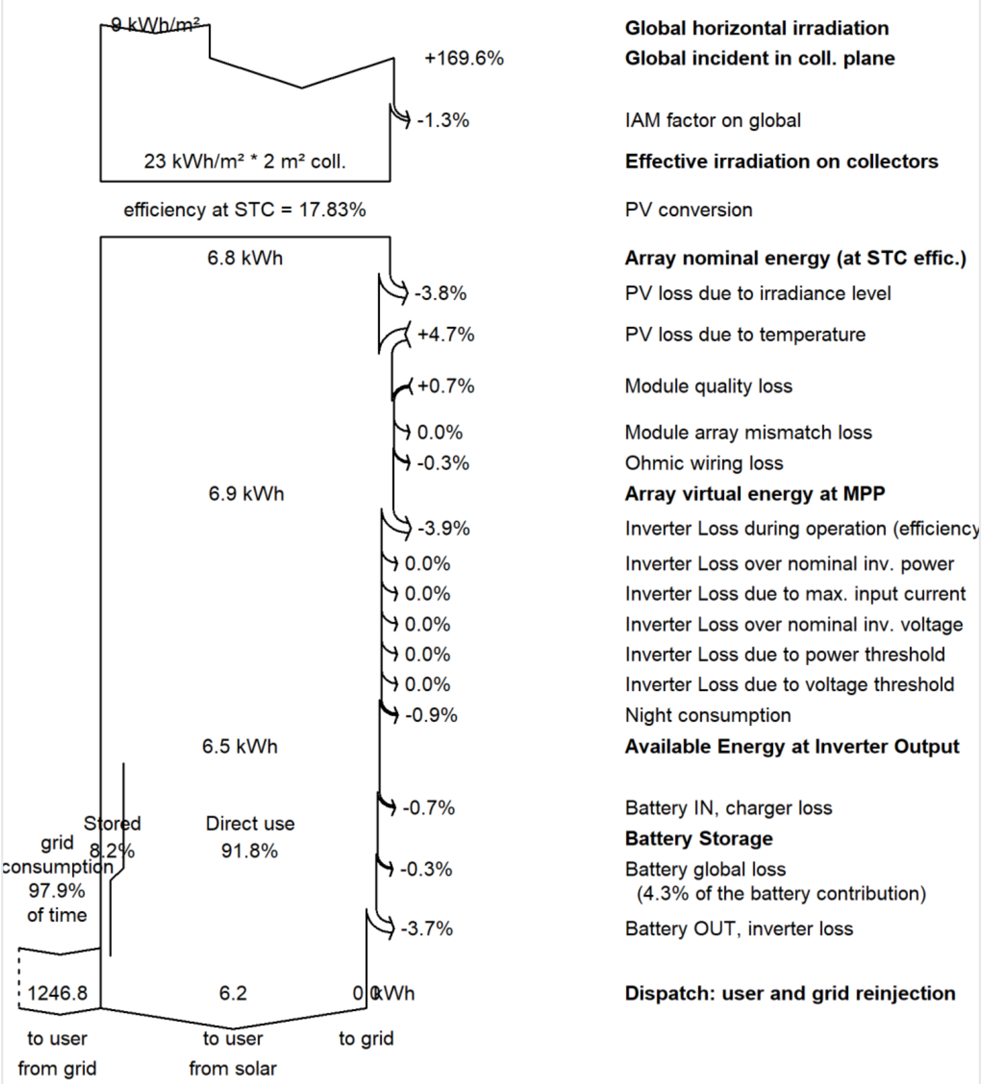

Loss diagram for "New simulation variant" - July
135 kWh/m²
Global horizontal irradiation
+11.0%
Global incident in coll. plane
-2.5%
IAM factor on global
145 kWh/m² * 2 m² coll.
Effective irradiation on collectors
efficiency at STC = 17.83%
PV conversion
42.2 kWh
Array nominal energy (at STC effic.)
-1.0%
PV loss due to irradiance level
-6.7%
PV loss due to temperature
+0.8%
Module quality loss
0.0%
Module array mismatch loss
-0.9%
Ohmic wiring loss
38.9 kWh
Array virtual energy at MPP
-3.2%
Inverter Loss during operation (efficiency
0.0%
Inverter Loss over nominal inv. power
0.0%
Inverter Loss due to max. input current
0.0%
Inverter Loss over nominal inv. voltage
0.0%
Inverter Loss due to power threshold
0.0%
Inverter Loss due to voltage threshold
-0.1%
Night consumption
37.6 kWh
Available Energy at Inverter Output
-0.8%
Battery IN, charger loss
Stored
14.8%
Direct use
85.2%
Battery Storage
grid
consumption
86.5%
of time
-0.6%
Battery global loss
(4.4% of the battery contribution)
-6.7%
Battery OUT, inverter loss
1218.4
34.6
0.0 kWh
Dispatch: user and grid reinjection
to user
from grid
to user
from solar
to grid


Loss diagram for "New simulation variant" - August
84 kWh/m²
Global horizontal irradiation
+42.8%
Global incident in coll. plane
-2.0%
IAM factor on global
117 kWh/m² * 2 m² coll.
Effective irradiation on collectors
efficiency at STC = 17.83%
PV conversion
34.0 kWh
Array nominal energy (at STC effic.)
-1.1%
PV loss due to irradiance level
-4.9%
PV loss due to temperature
+0.8%
Module quality loss
0.0%
Module array mismatch loss
-0.9%
Ohmic wiring loss
31.9 kWh
Array virtual energy at MPP
-3.1%
Inverter Loss during operation (efficiency
0.0%
Inverter Loss over nominal inv. power
0.0%
Inverter Loss due to max. input current
0.0%
Inverter Loss over nominal inv. voltage
0.0%
Inverter Loss due to power threshold
0.0%
Inverter Loss due to voltage threshold
-0.1%
Night consumption
30.9 kWh
Available Energy at Inverter Output
-0.8%
Battery IN, charger loss
Stored 15.7%
Direct use 84.3%
Battery Storage
grid consumption 88.3% of time
-0.6%
Battery global loss
(4.0% of the battery contribution)
-7.6%
Battery OUT, inverter loss
1184.5
28.1
0.0 kWh
Dispatch: user and grid reinjection
to user from grid
to user from solar
to grid

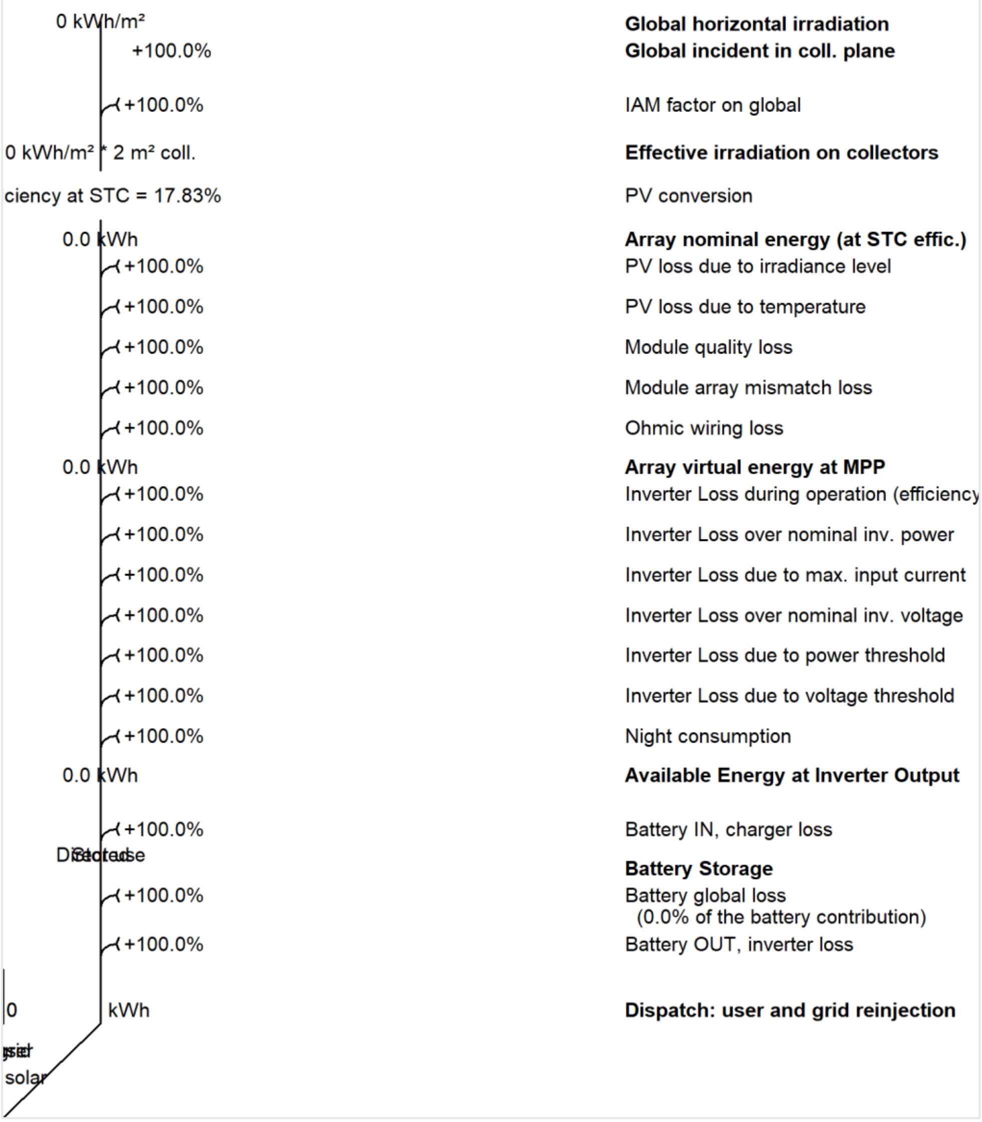

Loss diagram for "New simulation variant" - September
46 kWh/m²
+73.0%
-1.6%
79 kWh/m² * 2 m² coll.
efficiency at STC = 17.83%
23.0 kWh
-1.3%
-2.1%
+0.7%
0.0%
-0.8%
22.2 kWh
-3.1%
0.0%
0.0%
0.0%
0.0%
0.0%
-0.2%
21.4 kWh
-0.8%
Stored 14.6%
Direct use 85.4%
grid consumption 91.4% of time
-0.5%
-8.2%
1233.6
19.4
0.0 kWh
to user from grid
to user from solar
to grid
Global horizontal irradiation
Global incident in coll. plane
IAM factor on global
Effective irradiation on collectors
PV conversion
Array nominal energy (at STC effic.)
PV loss due to irradiance level
PV loss due to temperature
Module quality loss
Module array mismatch loss
Ohmic wiring loss
Array virtual energy at MPP
Inverter Loss during operation (efficiency
Inverter Loss over nominal inv. power
Inverter Loss due to max. input current
Inverter Loss over nominal inv. voltage
Inverter Loss due to power threshold
Inverter Loss due to voltage threshold
Night consumption
Available Energy at Inverter Output
Battery IN, charger loss
Battery Storage
Battery global loss
(3.9% of the battery contribution)
Battery OUT, inverter loss
Dispatch: user and grid reinjection


Loss diagram for "New simulation variant" - October
17 kWh/m²
+116.3%
-1.3%
36 kWh/m² * 2 m² coll.
efficiency at STC = 17.83%
10.4 kWh
-2.7%
+1.5%
+0.8%
0.0%
-0.5%
10.3 kWh
-3.5%
0.0%
0.0%
0.0%
0.0%
0.0%
-0.5%
9.9 kWh
-0.7%
Stored 8.8%
Direct use 91.2%
grid consumption 96.6% of time
-0.3%
-4.2%
1203.2
9.4
0.0 kWh
to user from grid
to user from solar
to grid
Global horizontal irradiation
Global incident in coll. plane
IAM factor on global
Effective irradiation on collectors
PV conversion
Array nominal energy (at STC effic.)
PV loss due to irradiance level
PV loss due to temperature
Module quality loss
Module array mismatch loss
Ohmic wiring loss
Array virtual energy at MPP
Inverter Loss during operation (efficiency
Inverter Loss over nominal inv. power
Inverter Loss due to max. input current
Inverter Loss over nominal inv. voltage
Inverter Loss due to power threshold
Inverter Loss due to voltage threshold
Night consumption
Available Energy at Inverter Output
Battery IN, charger loss
Battery Storage
Battery global loss
(4.3% of the battery contribution)
Battery OUT, inverter loss
Dispatch: user and grid reinjection

Loss diagram for "New simulation variant" - November



Loss diagram for "New simulation variant" - December



Loss calculations in the distribution network for a house connected to the national distribution grid.

ABB Australia Pty Limited

Transformer Technical Data Sheet

1LAP016375 **Revision A**

Engineering Department

March 18th, 2011 Page 1 of 1

Project Name:	
Reference Number:	

General Specification

Transformer Type		Oil Filled / Sealed
Standard		AS 60076
Installation		Indoor / Outdoor
Number of Phases		3
Frequency	[Hz]	50
Rated Power	[kVA]	**500**
Rated High Voltage	[V]	**11000**
Rated Low Voltage	[V]	433
Tapping on HV (Off circuit tap changer)		+4, -2 x 2.5%
Vector group		Dyn11
Type of cooling		ONAN
Temperature Rise (Oil/Winding)	[°C]	50/55
Conductor Material (HV/LV)		Aluminium/Aluminium
Maximum Ambient Temperature	[°C]	40
Altitude	[m]	< 1000
Insulation Class		A
Oil Type		Mineral Oil - Uninhibited
External Surface Treatment		HDG600P7 (Galvanising + Painting)
Colour		N42 Storm Grey

Technical Characteristics

No load loss	[W]	750
Load loss	[W]	5000
Impedance	[%]	4
Efficiency at 50% Load, 1.0PF	[%]	99.21%
Basic Impulse Level	[kV]	95
Sound Power Level	[dBA]	62

Overall Dimensions

Height	[mm]	1700
Length	[mm]	1830
Width	[mm]	2150
Oil Volume	[L]	1058
Total Mass	[kg]	2990

Standard Accessories	Optional Accessories
Pressure Relief Valve with contacts	
Oil Temperature Indicator with contact	
Oil Level Sight	

Kortslutningsniveau for NS 2761. De er som følger med nuværende netkonfiguration.

Datasæt : ALLAN_Total_25_05_2015. Beregningsår 2015.

Aktiv belastning er skaleret med 70.0 %, reaktiv 70.0 %
Aktiv vindmølleprod. i procent af max. 50, reaktiv 75 % (115.688 MW)
Sammenlægning internt i 12 knudepunkter.
Uden generatorer.

****

Resultat fra kortslutningsberegninger i 2761.
Knudepunktet er et 20.000 kV IT-net.

Nærmeste transformator :
Primærside : SDT2-KT1 Mærkespænding : 60.000 kV
Sekundærside : SDT1-S1 Mærkespænding : 20.000 kV
Koblingsgruppe : YNyn0 Mærkeydelse : 10000 kVA

Max. kortslutningsstrømme :		Temp (C)	Faktor
3-faset kortslutning	: 2.811 kA		
2-faset kortslutning	: 2.434 kA	20.0	1.10
Kortslutningseffekt	: 97.369 MVA		

Imp. plus-systemet R: 1.040 Ohm X: 4.398 Ohm Z: 4.519 Ohm Cos(phi): 0.230

Min. kortslutningsstrømme :		Temp (C)	Faktor
3-faset kortslutning	: 2.542 kA		
2-faset kortslutning	: 2.201 kA	90.0	1.00
Kortslutningseffekt	: 88.057 MVA		

Imp. plus-systemet R: 1.262 Ohm X: 4.364 Ohm Z: 4.543 Ohm Cos(phi): 0.278

****

Calculation about trans:

$Un1 := 10\ kV$ $Un2 := \frac{10000\ V}{25} = 400\ V$

$S_{KN.max} := 97.369\ MVA \angle -acos(0.230) = (22.395 - 94.759i)\ MVA$

$S_{KN.min} := 88.0\ 57\ MVA \angle -acos(0.278) = (1.394 \cdot 10^3 - 4.818i \cdot 10^3)\ MVA$

$Z_{Net.min} := \frac{Un1^2}{S_{KN.max}} = (236.21 + 999.49i)\ m\Omega$

$Z_{Net.max} := \frac{Un1^2}{S_{KN.min}} = (5.54 + 19.15i)\ m\Omega$

$Z'_{Net.min} := \frac{Un2^2}{S_{KN.max}} = (0.38 + 1.6i)\ m\Omega$

$Z'_{Net.max} := \frac{Un2^2}{S_{KN.min}} = (0.01 + 0.03i)\ m\Omega$

$t_{hak.linie} := 1\ s$

$I_{hak.linie} := 250\ A$

Transformerdata:

Opgivne værdier:

$Un1_{T1} := 10\ kV$ $Un2_{T1} := 400\ V$

$S_{N.T1} := 500\ kVA$

$e_{k.T1} := 5$

$P_{Cu.T1} := 4250\ W$

Udregninger:

$Z_{T1} := \frac{Un1_{T1}^2 \cdot e_{k.T1}}{S_{N.T1} \cdot 100} = 10\ \Omega$

$Z'_{T1} := \frac{Un2_{T1}^2 \cdot e_{k.T1}}{S_{N.T1} \cdot 100} = 16\ m\Omega$

$n_{T1} := \frac{Un1_{T1}}{Un2_{T1}} = 25$

$I_{B.T1} := \frac{S_{N.T1}}{Un1_{T1} \cdot \sqrt{3}} = 28.868\ A$

$I'_{B.T1} := \frac{S_{N.T1}}{Un2_{T1} \cdot \sqrt{3}} = 721.688\ A$

$R_{T1} := \frac{P_{Cu.T1}}{3 \cdot I_{B.T1}^2} = 1.7\ \Omega$

$X_{T1} := \sqrt{Z_{T1}^2 - R_{T1}^2} = 9.854\ \Omega$

$tan\varphi_{T1} := \frac{1}{\left(\frac{R_{T1}}{X_{T1}}\right)} = 5.797$

$\varphi_{T1} := -atan(tan\varphi_{T1}) = -80.212\ deg$

$Z_{T1} := \frac{Un1_{T1}^2 \cdot e_{k.T1}}{S_{N.T1} \cdot 100} \angle -\varphi_{T1} = (10 \angle 80.212°)\ \Omega$

$Z'_{T1} := \frac{Un2_{T1}^2 \cdot e_{k.T1}}{S_{N.T1} \cdot 100} \angle -\varphi_{T1} = (16 \angle 80.212°)\ m\Omega$

$S_{N.T1} := S_{N.T1} \angle \varphi_{T1} = (500 \angle -80.212°)\ kVA$

$$I_{kmax} := \frac{Un2}{(Z'_{T1} + Z'_{Net}) \cdot \sqrt{3}} = (15.99 \angle -77.534°)\ kA$$

$$z_n = \frac{Un^2}{sk} = \frac{400^2}{97{,}369 \times 10^6} = 1.64 \times 10^{-3}$$

$$R_N = z_n \times \cos\varphi = 164 \times 10^{-3} x \cos(0.230) = 1{,}62 \times 10^{-3}$$

$$X_N = z_n \times \sin\varphi = 164 \times 10^{-3} x \sin(0.230) = 6{,}58 \times 10^{-3}$$

$$z_n = 1.62 \times 10^{-3} + j6{,}5 \times 10^{-6}$$

2

$$z_T = \frac{ek \times Un^2}{100^x S_N} = \frac{4 \times 400^2}{100 \times 500} \times 10^{+3} = 0{,}0128^{12{,}8\times 10^{-3}}_{m\Omega}$$

$$R_T = \frac{P_{cu} \cdot \mathrm{U}_n 2}{s_n 2} = \frac{425 \times 400^2}{(500 \times 103)^2} = 2.72 \times 10^{-3} m\Omega$$

$$Z_T = \sqrt[1]{x_T^2 + R_T^2} \Rightarrow X_T = \sqrt[1]{Z_T^2 - R_T^2}$$

$$\Rightarrow X_T = \sqrt{(12.8 \times 10^{-3})^2 - (2.72 \times 10^{-3})^2} = 0{,}0124 m\Omega$$

$$z_T = 2{,}72 \times 10^{-3} + j_{0{,}0124 m\Omega}$$

3

$r_{240} = 0.0127$
$x_{240} = 0.083$

$$R_{stik} = \frac{r_{240\times 0{,}15}}{4} = 4{,}76 \times 10^{-3} m\Omega$$

$$x_{stik} = \frac{r_{2400\times 0{,}15}}{4} = 3{,}11 \times 10^{-3}$$

$$Z_{stik} = 4{,}76 \times 10^{-3} + j3{,}11 \times 10^{-3}$$

4

$r_{25} = 0.0727$
$x_{25} = 0.086$

$$R_{hand} = r_{25\times 0.04} = 0{,}029$$

$$X_{hand} = x_{25\times 0.04} = 3{,}44 \times 10^{-3}$$

$$Z_{hand} = 0{,}029 + j3{,}11 \times 10^{-3}$$

5

$r_{10} = 1{,}830$
$x_{10} = 0.089$

$$R_g = 0{,}023 \times 1.830 = 0.042$$

$$X_g = 0{,}023 \times 0.089 = 2.047 \times 10^{-3}$$

$$z_{grupp} = 0{,}042 \times j2{,}047 \times 10^{-3}$$

$r_{1{,}5} = 12{,}10$
$x_{1{,}5} = 0{,}113$

$$R_{til} = 12{,}10 \times 0{,}03 = 0{,}363$$

$$X_{til} = 0{,}1130 \times 0{,}03 = 3{,}39 \times 10^{-3}$$

$$z_{til} = 0{,}363 \times j3{,}39 \times 10^{-3}$$

1-2 og 3 fased kortslutning

$$I_1 f = I_{k_3 f}$$

$$\frac{Un}{\sqrt{3}\sqrt{(R_N + R_T)^2 + (x_N + x_T)^2}} = \frac{400}{\sqrt{3}\sqrt{(1{,}62 \times 10^{-3} + 2{,}72 \times 10^{-3})^2 + (6{,}5 \times 10^{-6} + 0{,}0124)^2}}$$

$$= \frac{400}{\sqrt{3}\sqrt{(1{,}62 \times 10^{-3} + 2{,}72 \times 10^{-3})^2 + (6{,}5 \times 10^{-6} + 0{,}0124 \times 10^{-3})^2}}$$

$$17094 \cong 170{,}94kA$$

$$I_{k_2 f} = \frac{\sqrt{3}}{2} \cdot = 148.038kA$$

1-2 og 3 fased kortslutning for stikkontakter

Størst 3-fased

$$I_{ksf\max} = \frac{Un}{\sqrt{30Z}}$$

$$ZR = R_N + R_T + R_{stik} + R_{hovd} + R_{gr} + R_{til}$$

$$ZR = 1{,}62 + 2{,}72 + 4{,}76 + 0{,}029 + 0{,}042 + 0{,}363 = 457{,}68m\Omega$$

$$Zx = X_N + X_T + X_{stik} + X_{hovd} + X_{gr} + X_{til}$$

$$Zx = 6{,}5 + 0{,}0124 + 3{,}11 + 3{,}44 + 2{,}047 + 3{,}39 = 19{,}72m\Omega$$

$$I_{ksf\max} = \frac{400}{\sqrt{3}\sqrt{(457{,}68)^2 + (19{,}72)^2 \times 10^{-3}}} = \frac{400}{793{,}460 \times 10^{-3}} = 504{,}12$$

$$I_{ksf\max} = 504{,}12A$$

Mindstw 3 fased

$$ZR = R_N + R_T + 1{,}5(R_{stik} + R_{hovd} + R_{gr} + R_{til)}$$

$$= 1{,}62 + 2{,}72 + 1{,}5\ (4{,}76 + 29 + 42 + 363) = 662{,}48m\Omega$$

$$Zx = X_N + X_T + X_{stik} + X_{hovd} + X_{gr} + X_{til} = 19{,}72m\Omega$$

$$z = \sqrt{ZR^2 + Zx^2} = 662{,}77m\Omega$$

$$I_{ksf\min} = \frac{400}{\sqrt{3 \times 662{,}77 \times 10^{-3}}} = 350{,}87m\Omega$$

Største 2 fased kortslutningsstrøm

$$\frac{\sqrt{3}}{2}x^{504,14} = 436.59A$$

Mindste 2 fased kortslutningsstrøm

$$\frac{\sqrt{3}}{2}x^{350,87} = 303.86A$$

Mindste 1 fased kortslutningsstrøm

$$I_{ksf\min} = \frac{Un}{\sqrt{3} \times \sqrt{ZR^2 + Zx^2}}$$

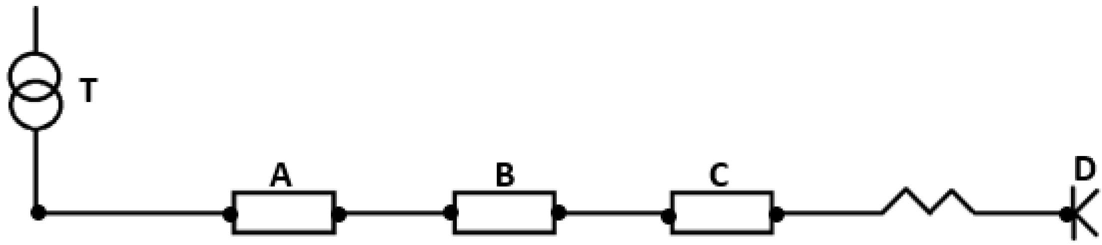
$$ZR = R_N + R_T + 2x1{,}5(R_{stik} + R_{hovd} + R_{gr} + R_{til})$$

= 1,62 + 2.72 + 2x1,5 (4,76+29+42+363) = 1320,62

$$Zx = X_N + X_T + 2(X_{stik} + X_{hovd} + X_{gr} + X_{til})$$

$$= 6{,}5 + 1{,}24 + 2(3{,}11 + 3{,}44 + 2{,}047 + 3{,}39) = 31{,}7$$

$$I_{ksf\min} = \frac{Un}{\sqrt{3} \times \sqrt{ZR^2 + Zx^2} \times 10^{-3}} = \frac{400}{2288{,}03 \times 10^{-3}} = 174{,}82A$$



$L = 150m = 0{,}15km$	$L = 40m = 0{,}04\ km$	$L = 23m = 0{,}023\ km$	$L = 40m = 0{,}03\ km$
$I_b = 368$	$I_b = 50A$	$I_b = 25A$	$I_b = 40A$
$r_L = 0{,}127$	$r_L = 0{,}757$	$r_L = 1{,}83$	$r_L = 12{,}1$
$x_L = 0{,}083$	$x_L = 0{,}686$	$x_L = 0{,}089$	$x_L = 0{,}113$

$$\boldsymbol{A}: R_L = 0{,}15 \times 0{,}127 = 0{,}019$$

$$\boldsymbol{A}: R_L = 0{,}15 \times 0{,}127 = 0{,}019$$

$$x_L = 0{,}15 \times 0{,}083 = 0{,}012$$

$$\boldsymbol{\Delta}_{\gamma} = \sqrt{3}\left(\frac{368\times 0{,}19\times\cos(0{,}9)}{4}\right) + \left(\frac{368\times 0{,}19\times\cos(0{,}9)}{4}\right) = 2{,}97\ v$$

$$\Delta_u\% = \%1.725$$

$$\boldsymbol{B}: R_L = 0{,}04\times 0{,}727 = 0{,}029$$

$$x_L = 0{,}04\times 0{,}086 = 3{,}44\mathrm{xl}$$

$$\boldsymbol{\Delta}_{\gamma} = \sqrt{3}(5\times 0{,}029\times\cos(0{,}9)) + (50\times 3{,}44\times\ 1^{-3}\ \times\sin(0{,}91)) = 2{,}5\ v$$

$$\Delta_u\% = \%1.625$$

$$\boldsymbol{C}: R_L = 0{,}23\times 0{,}727 = 0{,}016$$

$$x_L = 0{,}23\times 0{,}089 = 2{,}047\times\ 1^{-3}\sin(0{,}91)$$

$$\boldsymbol{\Delta}_{\gamma} = \sqrt{3}(25\times 0{,}016\cos(0{,}9)) + (25\times 0{,}47\times\ 1^{-3}\ \times\sin(0{,}91)) = 0{,}069\ v$$

$$\Delta_u\% = \%0{,}97$$

$$\boldsymbol{D}: R_L = 0{,}30\times 12{,}10\ = 0{,}363$$

$$x_L = 0{,}30\times 0{,}113 = 3{,}39\ \times\ 1^{-3}$$

$$\boldsymbol{\Delta}_{\gamma} = \sqrt{3}(40\times 0{,}363\cos(0{,}9)) + (40\times 3{,}39\times\ 1^{-3}\times\ \sin(0{,}91)) = 2{,}5v$$

$$\bar{\mathbf{z}}\boldsymbol{\Delta}_{\gamma} = 2{,}9 + 2.5 + 0.069 + 2.5 = 7.969$$

$$\Delta_u\% = \%1{,}99$$

Elregning

NRGi

Kundenr.
Kontonr. 110247094815
Fakturanr.

Fakturadato 16.05.2023

Kære kunde

Det er tid til at betale for dit elforbrug på Vangen 113, 2 tv, 9400 Nørresundby.

Din opgørelse for PERIODEN: 01.04.2023 - 30.04.2023

Du har brugt	209,740 kWh	423,01 kr.

Forbruget er inkl. abonnementer og faste gebyrer

Du skal i alt betale (inkl. moms) **423,01 kr.**

Bemærk, at du kan opleve mindre differencer mellem totalerne og summen af de enkelte poster, da beregningerne er foretaget med flere decimaler, end der vises på regningen.

Seneste betalingsdato er den 01.06.2023. Beløbet trækkes via Betalingsservice. Vil du

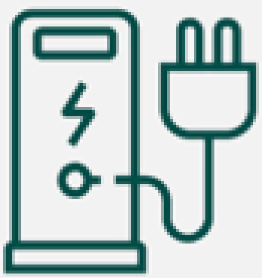
have flere detaljer? Se en specifikation af elregningen på næste side.

Har du spørgsmål? Så kontakt os på telefon 7011 4500.

Vi sætter strøm til mere end din bolig

Vi sikrer hver dag, at der er strøm i din bolig. Men hvorfor ikke også lade os sætte strøm til din elbil, hvis du har sådan en?

Vores ladeboks Zaptec Go er blandt de mindste på markedet. Den har et enkelt design og oplader ubesværet alle el- og plug-in-hybridbiler. Du får adgang til Monta-appen, som giver dig mulighed for at starte opladningen automatisk, når elprisen er lavest, følge dit forbrug til opladning og meget mere. Der indgår naturligvis også en grøn elaftale med en variabel pris i ladeleasingen.



Følg dit strømforbrug med NRGi app — App Store — Google Play

Side

NRGi Elhandel A/S CVR nr. 32 28

Detaljeret elregning

Din elregning dækker betaling for alt det, der hænger sammen med køb og levering af strøm til din adresse. Du betaler os for den strøm, du bruger. Betaling for transport af strømmen til din adresse sender vi direkte videre til dit netselskab, på samme måde somskatter og afgifter sendes direkte til staten.

Din opgørelse for PERIODEN: 01.04.2023 - 30.04.2023

	kWh	kr.	
Dit elselskab NRGi Elhandel A/S			
Strøm	209,740 x	1,12210	235,35 kr.
Abonnement til NRGi Elhandel A/S			16,25 kr.
Betalingsgebyr (heraf 4,35 kr. til Nets)			8,00 kr.
Dit netselskab Nord Energi Net A/S			
Nettarif C	209,740 x	0,30628	64,24 kr.
Abonnement, elmaaler			67,71 kr.
Staten			
Elafgift	209,740 x	0,01000	2,10 kr.
Systemtarif	209,740 x	0,06750	14,16 kr.
Transmissions nettarif	209,740 x	0,07250	15,20 kr.
I alt for perioden inkl. abonnementer og faste gebyrer			423,01 kr.
Svarende til en faktisk gennemsnitlig pris pr. kWh på			2,01 kr.

Bemærk, at du kan opleve mindre differencer mellem totalerne og summen af de enkelte poster, da beregningerne er foretaget med flere decimaler, end der vises på regningen.