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Project GreenCampus

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First reviewer: Dr.-Ing. Pascal Leibbrandt
University of Applied Science Nordhausen

ABSTRACT

The Project GreenCampus at Hochschule Nordhausen aims to make the campus more sustainable and environmentally friendly. The project includes a variety of initiatives to reduce the campus's carbon footprint and promote sustainable practices among students and staff. Some of the initiatives being implemented include the installation of energy-efficient lighting and appliances, the use of renewable energy sources, the implementation of waste reduction and recycling programs, and the promotion of sustainable transportation options.

The project involves the modelling of PV systems, AeroMine systems, and Geothermal Energy sources to provide energy to the campus. The project team has conducted a thorough analysis of the campus's energy consumption patterns and identified areas where renewable energy sources can be integrated.

The Project GreenCampus is not only environmentally beneficial but also financially sustainable. By generating electricity through renewable means, the campus will save on energy costs and reduce its reliance on non-renewable energy sources. The project also serves as an educational tool to raise awareness about the importance of renewable energy and its role in mitigating climate change.

The GreenCampus Project at Hochschule Nordhausen is a comprehensive approach to sustainability that demonstrates the institution's commitment to reducing its environmental impact and promoting sustainable practices. The project is an excellent example of how institutions can take an active role in mitigating climate change and promoting a sustainable future.

ABSTRAKT

Das Projekt GreenCampus an der Hochschule Nordhausen zielt darauf ab, den Campus nachhaltiger und umweltfreundlicher zu gestalten. Das Projekt umfasst eine Vielzahl von Initiativen zur Verringerung des CO_2-Fußabdrucks des Campus und zur Förderung nachhaltiger Praktiken bei Studierenden und Mitarbeitern. Zu den umgesetzten Initiativen gehören die Installation energieeffizienter Beleuchtung und Geräte, die Nutzung erneuerbarer Energiequellen, die Umsetzung von Abfallvermeidungs- und Recyclingprogrammen sowie die Förderung nachhaltiger Transportmöglichkeiten.

Das Projekt umfasst die Modellierung von PV-Systemen, AeroMine-Systemen und Geothermischen Energiequellen, um den Campus mit Energie zu versorgen. Das Projektteam hat eine gründliche Analyse der Energieverbrauchsmuster auf dem Campus durchgeführt und Bereiche ermittelt, in denen erneuerbare Energiequellen integriert werden können.

Das Projekt GreenCampus ist nicht nur ökologisch vorteilhaft, sondern auch finanziell nachhaltig. Durch die Erzeugung von Strom aus erneuerbaren Energien wird der Campus Energiekosten sparen und seine Abhängigkeit von nicht erneuerbaren Energiequellen verringern. Das Projekt dient auch als Bildungsinstrument, um das Bewusstsein für die Bedeutung erneuerbarer Energien und ihre Rolle bei der Eindämmung des Klimawandels zu schärfen.

Das GreenCampus Projekt an der Hochschule Nordhausen ist ein umfassender Ansatz zur Nachhaltigkeit, der das Engagement der Hochschule für die Verringerung ihrer Umweltauswirkungen und die Förderung nachhaltiger Praktiken unter Beweis stellt. Das Projekt ist ein hervorragendes Beispiel dafür, wie Hochschulen eine aktive Rolle bei der Abschwächung des Klimawandels und der Förderung einer nachhaltigen Zukunft übernehmen können.

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List of Abbreviations

PV	Photovoltaic
BDEW	Bundesverband der Energie und Wasserwirthschaft
PTC	Performance Test Conditions
STC	Standard Test Conditions
DHW	Domestic Hot Water
DC	Direct Current
AC	Alternating Current
SR	Sizing Ratio
CO_2	Carbon Dioxide
N_s	Number of Cells
I_{sc}	Closed Circuit Current
V_{oc}	Open Circuit Voltage
I_{mp}	Maximum Current
V_{mp}	Maximum Voltage
T_{NOCT}	Temperature at Nominal Test Conditions
KWh	Kilo Watt Hours
MWh	Mega Watt Hours
kW	Kilo Watt
MW	Mega Watt
KJ	Kilo Joule
KJ/Kg-K	Kilo Joule per Kilogram kelvin
R_{sh_ref}	Shunt Resistance
γ_r	Temperature Coefficient of Power
R_s	Resistance in Series
β_{oc}	Temperature Coefficient Voltage
α_{sc}	Temperature Coefficient of Current
N_{max}	Maximum Number of Panels
N_{min}	Minimum Number of Panels
$kWh/m^2/a$	Kilo Watt Hours per meter square per Annum
Mt	Mega tons
K	Temperature in Kelvin
λ	Thermal Conductivity
R	Thermal Resistance
e	Thickness
U	Heat Transfer Coefficient
m	Meter
mm	Milli Meter
Q	Heat demand (MWh)
$\dot{m}$	mass flow of water (Kg)

Cp	specific heat of water (4.2 KJ/Kg-K)
ΔT	Temperature difference
L	Liter
m^2	Meter Square
Kph	Kilometer per Hour
Mph	Miles per Hour
LCOE	Levelized Cost of Energy
CAPEX	Capital Expenditure
OPEX	Operational Expenditure
€	Euros

1. Introduction

1. Introduction

1.1 Background and context of the study

Universities have an important role in promoting sustainability and reducing their environmental impact. However, the implementation of sustainability initiatives in universities is still in its infancy, and more research is needed to understand how to integrate sustainability into the operations and culture of universities effectively. Hochschule Nordhausen, like many other universities, is facing the challenge of reducing its environmental impact and promoting sustainability. The university is committed to finding ways to reduce its carbon footprint and make a positive impact on the environment. The university is also focused on finding ways to make its operations more energy efficient and sustainable.

A Sustainable Campus is defined as an environmentally oriented campus that integrates environmental science into its policies, management, and scholarly activities. This also represents the implementation and integration of all managerial aspects and the best practices of sustainable development. Many universities worldwide have shown their commitments to implement this concept. This concept needs to be implemented because various studies show that the stakeholders of universities that implement the idea are significantly more satisfied and have better perceived life quality than those from non-implementing universities. Besides, Sustainable Campus implementation also helps energy conservation and efficiency.

While being a green sustainable campus that plays vital role in promoting sustainable development and gains center attention for learning, innovations and research. University will be leading role model and can show commitment towards challenging in climate change and environmental responsibility. In recent years, Hochschule Nordhausen has continued to grow and expand its programs and research initiatives. The university has a strong commitment to sustainability and has implemented several initiatives to reduce its environmental impact, including the use of renewable energy sources and energy-efficient buildings [1].

However, this task is not easy as the university is also facing the challenge of the energy crisis that has resulted from the ongoing conflict between Russia and Ukraine, which has led to significant disruptions in the natural gas supply to Europe, with the European Union imposing sanctions on Russian gas exports [2]. This has resulted in an energy crisis in many countries, as they struggle to find alternative sources of energy. This crisis has significant implications for efforts to reduce CO_2 emissions and combat climate change, thus this study aims to understand the potential of the Hochschule Nordhausen to reduce its environmental impact in this context, by identifying and evaluating the potential for renewable energy, energy efficiency, sustainable transportation, and waste reduction.

1.2 Purpose of the study

As of now, fossil fuels are the primary energy source used for generating electricity and providing space heating on our campus, but due to climate change, which is the most important and significant concern of our time, one must seek an alternative reliable energy source. Therefore, to take off a little load from the shoulders of mother nature, our group has taken though a small but much-needed step to fight against the dependency of our university's electricity and heating needs on fossil fuels.

The primary purpose of our study is to look for alternative renewable energy technologies, such as extracting power from the sun, wind, biodegradable wastes, etc. In this report one can see the various ideas to make use of renewable sources, for instance, the implementation of photovoltaic systems (PV) and solar thermal collectors on the rooftop of the various campus buildings, using bio-waste obtained from the campus's Mensa and other residential buildings to power our university's electricity and heat needs. Moreover, this study just not only focuses on the generation part but as well as the conservation part of electricity.

1.3 Research Objectives

Green campus initiatives are an important component of today's educational system, and institutions can lead the way in advancing these ideas throughout society. In order to promote a sustainable and environmentally friendly environment, our college started the green campus initiative. These projects' primary goals were to increase public awareness of the environment, promote the use of renewable energy sources, and promote energy-saving techniques.

University campuses are considered living laboratories to solve the problem of the energy crisis and make campus green. Living laboratories can simply defined as a collaborative space where students, faculty, and staff combine to tackle sustainability challenges through both education and practical research. The concept of a university as a living lab aims to unite facilities management and academics, offering students the opportunity to actively participate in addressing environmental issues [4].

The objectives of this research are mentioned as follows:

- Our main objective is to use different renewable energy sources, including photovoltaics, solar thermal energy, and many more, to make the entire campus green
- To assess the current energy consumption and identify opportunities for renewable energy generation on the Hochschule Nordhausen campus.
- To evaluate the potential for energy efficiency measures in buildings and infrastructure on campus.
- To investigate options for sustainable transportation for students and staff, including the feasibility of electric vehicles and car-sharing programs.
- To study the potential for waste reduction and recycling programs on campus.

- To conduct a cost-benefit analysis of the proposed sustainable initiatives to determine their economic feasibility.
- People have their individual choices which affect the environment. Energy consumption is considered as the root cause of global warming and pollution therefore objectives of energy saving is emission reduction, sustainable development, and public awareness.
- To provide practical recommendations for the implementation of sustainable initiatives at Hochschule Nordhausen that align with the university's goals for reducing their environmental impact and promoting sustainability.

1.4 Scope & limitations

Nowadays, every educational institute is trying to make a significant contribution towards renewable energy by replacing the conventional methods of energy supply with the renewable energy, different clean energy systems for sustainability and creating healthy living and learning environments. The scope of the project is limited to the university campus and this project has lasted for 6 months. Types of energy concepts focused in this study are Photovoltaics (PV) and Solar thermal energy. PV and Solar thermal systems will reduce the electricity and heat dependency on conventional sources which will reduce the CO_2 emissions significantly.

On the contrary, the initial costs of using these systems are very high. Furthermore, depending on the time of the day, and even the time of the year, the intensity of the sun varies. The amount of energy produced is affected by factors like snow, clouds, and foliage cover. The space required to install solar panels is high because compared to fossil fuels, solar panels need more space to produce the same amount of energy. Solar panels can be sensitive in terms of location, for instance, if the panels are shaded the solar cells cannot generate power. Additionally, trees must be cut down to solve the shading problem because they block the solar panels, which can be very harmful for the environment.

2. Literature Review

2. Literature Review

2.1 Overview of green universities

According to the information from the ‘Green Office Movement’ website, a green university is an educational institution that has made a commitment to sustainability and environmental stewardship. This commitment is reflected in the university's operations, curriculum, and research. A green university strives to reduce its environmental footprint by implementing initiatives that promote energy efficiency, renewable energy, sustainable transportation, and waste reduction. The university aims to achieve zero CO_2 emissions by purchasing renewable energy, promoting public transport, and encouraging the use of electric vehicles. Additionally, the university aims to achieve zero waste by implementing measures such as recycling, composting leftover food, reusing water, and purchasing products with a cradle-to-cradle design. The university also focuses on maximizing biodiversity by purchasing organic food, creating campus gardens, and banning toxic chemicals. The university's curriculum should include courses and programs that educate students on environmental issues and sustainability. The research conducted by the university should also focus on sustainability and environmental issues [4].

According to the ‘Green Metric ranking system’, Hochschule Trier-Umwelt Campus Birkenfeld was chosen as the greenest university out of 912 in 2021 [5]. The campus boasts an impressive annual electricity consumption of just 1000 MWh, which is 100% sourced from renewable energy. This was achieved through the installation of 6494 solar PV panels, as well as other renewable energy sources, resulting in the harvesting of 520 MWh of energy. Additionally, the university has implemented a state-of-the-art lighting system and innovative ventilation system, which further contribute to its sustainable efforts [6].

Wageningen University and Research has consistently been recognized as one of the world's most sustainable and green universities, having been ranked as the top in this category for four consecutive years (2017, 2018, 2019, and 2020). The university is a leader in renewable energy, generating power through wind turbines, solar thermal storage, and PV panels. Additionally, the university has implemented a comprehensive waste management system and promotes the use of electric vehicles (E-mobility) on campus. Furthermore, the university boasts natural gardens that are not only beautiful but also contribute to biodiversity conservation [7].

The University of Nottingham has been recognized as one of the world's most sustainable universities, having been ranked 2nd in 2021 by the Green 65fxc Metric ranking system [8]. The university is a pioneer in carbon-neutral built in the UK and has achieved this by implementing a wide range of sustainability initiatives, including improving the energy efficiency of buildings and equipment, generating energy from renewable energy systems, promoting waste recycling, and encouraging the use of electric vehicles (E-mobility) on campus [9].

The University of Iowa has been recognized as one of the most energy-efficient universities in the country, having been ranked No.3 by the Environmental Protection Agency (EPA) in 2016 for its consumption of green energy. The university generates an impressive 84% of its energy consumption from green sources, totaling 251 million kWh [10]. The majority of this energy is produced through bioenergy, utilizing sustainable biomasses such as oat hulls, miscanthus grass, and energy pellets [11]. In addition to its bioenergy efforts, the university has also implemented electric vehicle charging stations, incorporated smart grid technology, and installed a thin-film solar roof, which generates an additional 384 kW of electricity [12].

The University of Missouri has been recognized for its efforts in sustainability and environmental stewardship, having been ranked No.22 by the Environmental Protection Agency (EPA) for its consumption of green energy in 2016 [10]. The university is able to cover 30% of its energy consumption through green sources, amounting to 69,723,855 kWh. This has been made possible through a variety of initiatives, including harvesting energy from a 20-kW wind turbine, a 34 kW PV system consisting of 144 polycrystalline solar panels, implementing solar thermal heating systems with evacuated tube technology, and utilizing a biomass boiler that burns 127,000 tons of biomass sourced from sawmills and wood product companies [13].

2.2 Overview of previous research on heat energy supply

According to research in 'Heat Transfer A Practical Approach 2nd Edition' done by Yunus A Cengel states that, heat has always been perceived as something that produces in us a warming sensation. The understanding of heat is dated back since 19th century. Heat can therefore be defined as the energy associated with the random motion of atoms and molecules as tiny particles which are in motion, thus possessing kinetic energy. In the current energy crisis, efficient energy supply in building becomes very important. In addition, the current state of climate change, causing drastic environmental problem such as global warming as a result of fossil fuels activities has resulted to the need in supplying renewable heat in buildings. On the other hand, heat energy supply to buildings and various establishments, has important role to play in our daily living, such has, helping in meeting our temperature need for space heating (40°C) and domestic hot water use (55°C). To considering the appropriate heat supply, we have considered the heat loss, heat gain and building insulation, as this will be used in the determination of the heating supply for space heating, thereby generating a threshold in the determination of the complete heating demand [30].

2.3 Overview of previous research on electricity supply

R. Balasoltanov, T. Raddau and S. Schubert (2014) in "Projektarbeitsmodul Thermische Energiesysteme: Energiecampus" determined and calculated the electric energy supply for Hochschule Nordhausen which was studied with regard to the "Project GreenCampus" where specific data was available through the thesis work. The thesis work describes the specific as well as average electric energy consumption of the University for the years 2011 to 2013. The campus is divided into two subdivisions, North Campus and South Campus to simplify the calculations from the data that was available and the internal measurements. The energy consumption for every building on the campus is identified through this process. Also, the parameters like the Energy Load profiles, peak demands, weekly energy demand, base load, net floor areas and other parameters regarding the electrical power were calculated [72].

The data for energy consumption is obtained from the energy supplier in terms of quarter-hourly, monthly and annual consumptions. Also, specific energy consumption for every building is obtained by the internal readings from different meters installed by the energy supplier in the University. This helps to determine the total annual energy consumption for the university as well as for the objects (buildings) which further determines the consumption share of each building with respect to total energy consumption. The monthly readings and bills were used to plot the graphs and determine the annual load profiles for every year along with an average load curve for the University. However, the specific figures for monthly consumption are not mentioned but can be roughly determined through the plotted graphs. The energy demand for the University is calculated through the quarter-hourly readings provided by the energy supplier. This data is compiled to get an hourly load curve specifically for the year 2012 [72].

"Bundesverband der Energie und Wasserwirthschaft (BDEW)" [73] source provides data specific to electrical and heat energy and water consumption for various types of buildings in Germany. The data from Balasoltanov etal. worl, was compiled with standard data evaluated by the BDEW for commercial buildings across Germany. The profile categories and the factors influencing the categories are mentioned in the source to get the data regarding energy demand. The help of standard data was used due to the lack of energy bills as compared to the previous work based on energy bills from the energy supplier. The standard data includes the average quarter-hourly energy demand with respect to seasons and daily working hours of commercial buildings [73].

2.4 Literature Review on Solarrechner

The 'Thuringian Solarrechner' Provides assistance to calculate the yield of photovoltaic systems and solar thermal systems. The Thuringian Solarrechner is a free service from the state energy agency ThEGA and the Thuringian Ministry of the Environment. The online advice is therefore free of commercial interests and is manufacturer-neutral and independent. This website helps citizens, companies and municipalities to calculate the profitability of a solar system in just a few minutes. With so-called aerial survey data, the Thuringian solar calculator realistically records all roofs in the Free State. It can automatically analyze the pitch, size, orientation and shading of a roof. In addition, there is the calculation of solar radiation and the expected yields.

In order to determine the potential of PV or solar thermal systems, the address is important so that the software can find the house or the corresponding roof. The current power consumption is just as important for the profitability calculation, in order to be able to specify the level of personal consumption precisely. If you do not know the current power consumption, the calculator also calculates this indirectly via the size of the household (number of residents). Navigating the building can be done by either clicking on district and zooming in further, or using the address entered in the top bar directly.

2.5 Overview of previous research on solar-shaded parking for transport concept

Mr. Sreenath and Sudhakar examined ‘The Effectiveness of a fully Solar-Powered Airport’. Specifically, the 12 MWp grid-connected PV system located at Cochin International Airport in India. The study, based on one year of operational data, found that the solar PV system had an average performance ratio of 86.56% and a capacity utilization factor of 20.12%. Additionally, simulation software such as PVsyst and SolarGis were found to accurately predict the solar plant's performance. The study also showed that the solar-powered airport was effective in reducing carbon emissions, leading to a clean and sustainable airport. The study's conclusions suggest that buffer zones around airports are suitable for utility-scale PV power plants and that the initial investment in solar-powered airports is high, but the net present value of the project is positive. The Cochin airport serves as a best practice for solar-powered airports that can be adopted globally [14].

Raghul Suraj studied ‘The Design of a Solar Parking lot for 20 Electric Vehicles (EVs)’ in St.John’s, Newfoundland, Canada. The site selected is near the Canada National Research Council building located in Memorial University of Newfoundland. The Smart EQ For Two was used as the EV for the design and the system was optimized using the Homer software. The proposed charging infrastructure is equipped with current sensors that communicate power generation and consumption data in real-time to the cloud for direct PV run or utilizing the excess power stored in the battery bank. The system operates primarily on power produced by PV until there is a need for the battery to supply power. The paper presents complete system design and simulation results, it also explains the site details and calculations including the selected site, solar insolation and clearness index, load calculation and photovoltaic panel area calculation. Overall, the proposed solar parking lot design is a practical solution for meeting the energy demand of EVs using renewable energy resources [15].

The article ‘Rooftop photovoltaic parking lots to support electric vehicles charging: A comprehensive survey’ by Gerardo J. Osorio, Matthew Gough, and Mohamed Lotfi, discusses the potential for integration of electric vehicles (EVs) and solar energy systems through the creation of solar PV-fitted parking lots. The authors note that while EVs offer significant benefits in terms of minimal greenhouse gas emissions and reduced pollution, there are significant challenges in integrating them into power systems. The article presents a comprehensive survey of current concepts and technologies in PV panels, EVs, and batteries, and how they can be applied in the concept of solar parking lots. The authors note that while there are challenges in terms of power stability and flexibility, there is potential for emissions reduction and energy cost reductions through the integration of rooftop PV and EVs in urban areas. They also discuss how EV batteries can be used as a flexible reserve for providing regulation electricity markets, but note that due to the stochastic nature of EVs and the power grid, realizing this potential is challenging [16].

This research paper by A. Iringová , M. Kovačic focuses on the design and optimization of photovoltaic (PV) systems in a parking garage. The study takes place in Žilina and aims to maximize the efficiency of electricity production from the PV panels. The authors analyze several variants for the layout and inclination of the panels, taking into account the local climate conditions. The results of the economic analysis showed that the optimal solution is to install PV panels with monocrystalline cells on the roof of the parking garage, which can cover the energy consumption for the building and 6 charging stations [17]. The authors highlight the importance of renewable energy sources and the role of photovoltaic technology in reducing carbon emissions in the transportation sector. They mention that the integration of PV panels into building envelopes is an environmentally friendly solution, as the electricity generator is located at the point of consumption. The authors also mention that there is a lack of PV systems in parking garages, despite the potential to produce electricity for electric vehicle charging stations.

The data from the "PVGIS-SARAH" database showed that the solar radiation in Žilina is capable of covering the current demand for electricity in parking garages. According to the data from the European Association for the PV Industry (EPIA), 40 GW of solar PV systems have been installed globally, indicating a growing trend for renewable energy. Overall, this research paper provides a practical case study for the design and optimization of photovoltaic systems in a parking garage. The authors emphasize the importance of reducing carbon emissions and the benefits of using renewable energy sources [18].

2.6 Overview of previous research on Economic Analysis

'Stanford University' has been actively working on transition to renewable energy as part of its commitment to sustainability and reducing its carbon footprint. Here are some key steps the university has taken in this transition

Solar Energy: A typical rooftop solar panel system can generate approximately 1 kilowatt (kW) of energy per 100 square feet of rooftop space. A 2 megawatt (MW) solar farm, such as those implemented by Stanford University, can generate approximately 2 million kilowatt-hours (kWh) of energy per year.

Wind Energy: Stanford University has also installed two wind turbines on-campus, which generate over 1 million kWh of electricity per year.

Geothermal Energy: In addition to solar and wind energy, Stanford University uses geothermal energy to heat and cool some of its buildings. The university has a system of underground pipes that circulate water to exchange heat with the earth, providing a sustainable source of heating and cooling.

Energy Efficiency: Energy efficiency measures, such as upgrading building insulation, installing efficient lighting systems, and improving heating, ventilation, and air conditioning (HVAC) systems, can result in significant energy savings. For example, upgrading to efficient lighting systems can result in energy savings of up to 75% compared to traditional lighting systems.

Energy Storage: Energy storage systems, such as batteries, can store excess energy generated by renewable energy sources for use during periods of low generation. These systems can result in improved energy security and reduced reliance on fossil fuels.

These initiatives have helped Stanford significantly reduce its carbon footprint and move closer to its goal of becoming carbon neutral by 2025. The university continues to explore new ways to incorporate renewable energy into its operations and is committed to reducing its environmental impact [59].

‘Rutgers University’ has implemented several solar energy projects on its campuses, including the installation of rooftop solar panels and the development of a 2.5-megawatt solar farm. The solar panels are connected to the electrical grid and generate clean, renewable energy that can be used to power the university's buildings and operations. These projects have helped to reduce the university's reliance on fossil fuels and generate clean, renewable energy.

Sustainability Goals: Rutgers University has set ambitious sustainability goals, including a commitment to reducing its carbon footprint and becoming a more sustainable institution. The university's efforts to transition to renewable energy and reduce its carbon footprint have been successful, and it continues to work towards its sustainability goals.

Campus-Wide Efforts: University has implemented a variety of programs and initiatives to promote sustainability and transition to renewable energy across its campuses. These efforts include promoting sustainable transportation options, reducing waste, and increasing energy efficiency.

Community Involvement: Rutgers University has also worked with the local community to promote sustainability and transition to renewable energy. This has included partnering with local organizations, promoting renewable energy education and awareness, and working to increase access to renewable energy in the surrounding area.

Building Management Systems: Rutgers University has also implemented building management systems to control and monitor energy use in its buildings. These systems allow the university to monitor energy consumption in real-time, track energy use patterns, and make adjustments to improve energy efficiency.

Energy Storage: To maximize the benefits of renewable energy, Rutgers University has also implemented energy storage systems, such as batteries, to store excess energy generated by the solar panels. This allows the university to use the stored energy during periods of low solar generation, reducing its reliance on fossil fuels and improving its energy security.

Renewable Energy Credits: To offset its remaining carbon footprint, Rutgers University also participates in carbon offset programs and purchases renewable energy credits. This helps to further reduce the university's carbon footprint and promote the development of renewable energy sources

These efforts demonstrate Rutgers University's commitment to sustainability and its progress in transitioning to renewable energy. By reducing its carbon footprint, increasing energy efficiency, and promoting sustainable practices, Rutgers is working to create a more sustainable future for its students, faculty, and the surrounding community [60].

2.7 Overview of previous research on energy saving options

Kailei Wu (July 2019) did work on ‘Research on the energy audit from the perspective of environmental protection’; it is found that energy saving and environmental preservation are becoming increasingly crucial as the social economy continues to expand. The energy audit helps businesses utilize energy resources wisely and increase energy efficiency by integrating the management and control techniques of audit into their energy management. Additionally, it can support the sustainable growth of the economy and society. So, it becomes important to pay attention to the energy audit and to management in the organization for saving energy [19].

Michael Sony and Nandakumar Mekoth (May 2018) conducted a survey to determine why customers in India are unconcerned about energy-saving behaviors. They did a survey to solve an unresolved paradox related to electrical energy saving behavior. There are several studies on energy-saving practices; however, in their study, they emphasize that there is still a significant amount of untapped potential in terms of electricity energy-saving practices. They use grounded theory mythology for surveys. The fundamental processes in the analysis of qualitative data include data coding, data merging into wider categories and themes, and outcome interpretation [20].

(Nikolay Vatin et al. August 2014) worked on ‘Energy saving at home’. The article reveals the primary guidelines of saving heat, electricity and water at home. It also covers the methods for encouraging energy conservation and efficiency among the common people. It mainly concentrates on mass education and technical training for energy conservation professionals [21].

Ramya .L.N. (November 2015) performed a case study on energy conservation by considering the loads of a classroom in an educational institution and the energy consumed by the present loads, recommending energy-efficient appliances and an efficient yet simple sensor-based model to reduce the energy consumption, and comparing the results. He states that "energy conservation can be the best solution for the rising energy demand." Energy conservation is the practice of using less energy to reduce energy consumption. He also mentions that energy audits are an important way to improve energy conservation [22].

Zaneta Simanaviciene et al (April 2015) summarize the energy-saving potential of shifting population behavior in Switzerland, Germany, the United Kingdom, the Netherlands, and the United States. The study's goal is to examine international studies on behavior change and energy conservation. The scientific findings suggest that habits and routine procedure changes could be made with the help of measures like information disclosure, target-setting, feedback on energy use, and impact on society. However, most of the studies that were looked at had a number of methodological flaws, such as using only one type of instrument or using a few but failing to distinguish between them. According to studies, getting timely feedback on one's energy-consumption habits encourages behavior modification. Several macro-level and individualized elements are impacted by people's behavior in connection to energy consumption, according to assessments of the energy-saving potential in modifying people's behavior conducted in Switzerland, Germany, the United Kingdom, Netherlands, and the United States. Technological advancement, economic growth, demographic, institutional, and cultural nation elements are examples of macro-level variables. Personal factors include characteristics of an individual, such as attitudes, beliefs, norms, motivation, skills, knowledge, habits, and routines [23].

Yusaku Fujii et al. (January 2013) developed the project of smart street light systems. The street light system used in this project turns on when needed and turns off when not. The street lights, which switch on automatically when it gets dark and turn off automatically when it becomes bright, use a significant amount of electricity worldwide at the moment. This is a major source of energy waste that has to be changed. A LED light, a brightness sensor, a motion sensor, and a short-range communication network make up the smart street light system. When no one is around, the lights switch off or reduce power before walkers and cars arrive. Since the entire street lamps switch on before they arrive, it will be impossible for pedestrians and car drivers to tell our smart street lamps apart from the traditional street lights [24].

Marco Casini (May 2015) designed smart windows for building energy efficiency that not only reduce heat loss but also control incoming solar radiation to maximize solar gain in winter and minimize it in summer, while also ensuring the best natural lighting conditions with no glare. He found that these new dynamic windows, the electro chromic ones in particular, are proving to be more effective than traditional static systems—low-e selective glazing and automatic shading devices—at reducing energy consumption for lighting and air conditioning and providing greater comfort to users. The article offers an analysis of the different types of dynamic glazing on the market, with both passive and active control, illustrating their potential uses and the benefits achieved in terms of energy efficiency, environmental comfort, and architectural quality in both new construction and the requalification of existing buildings [25].

Saeed Kamali et al. (January 2014) introduced the concept of Building Energy Management System (BEMS) to tackle the existing energy problem. The rise in energy use, particularly in buildings, has made energy efficiency and savings techniques a major focus of energy policy in the majority of countries. Smart buildings, which have a dynamic environment, are made accessible by the integration of four key components: systems, structure, service, management, and their interactions. These advantages are provided by intelligent control systems in intelligent buildings. While introducing energy management in buildings, this study also examines its applications and the implications they have on managing and optimizing energy usage. For this study, a case study office tower in San Francisco, California, measuring 66,943 square feet, is used. By using BMS in this building, energy usage was cut in half [26].

An existing method for determining thermal stratification in combination storage tanks based on the second law of thermodynamics, the entropy balance of the storage system, was applied to the measurement of hot water storage tanks. The updated procedure uses the EN 16147 extraction profile to test the stratification efficiency of different sizes of storage tanks and adjusts the size of the collector array to the extraction profile when using solar thermal systems. The test procedure obtained was applied to several tanks and the results were evaluated. They found that the efficiency of storage and the effect of charging on operating modes are very different. The very well-tiered storage concept not only increases comfort and creates more hygienic conditions, but in combination with a heat pump it uses up to 40% more electrical energy compared to other storage systems. save money. These results highlight the need for an assessment of the stratification efficiency of domestic hot water storage tanks. This can be done using the method presented here, the measurements carried out demonstrate the applicability of the method based on different storage concepts and storage sizes, whereby an objective evaluation of the tested storage based on stratification efficiency is consistent with the expected calculated electrical energy requirements [27].

Minhwi Kim (2022) developed a positive energy community for renewable energy sharing community and investigated the positive energy performance of the proposed community compared with conventional community. The selected case study positive energy community has 56 houses and 2 non-residential buildings. This positive energy community is composed of building integrated photovoltaics, Battery Energy Storage System, and Thermal Energy Storage System. The community energy management system was operated to monitoring the community energy performance and energy trading of inner and outer community. This research presents the positive energy performance and economic benefit of the proposed community. It was found that the proposed community has 229% of renewable energy penetration rate and about 30% of self-consumption rates can be improved compared with the conventional community [71].

Yuxin Huang (January 2020) knew that reducing the setpoint temperature in all types of buildings is an effective means of saving heating energy. This study focuses on heating demand savings in the same building for different functional uses, based on the same climatic background and the same reduction in heating setpoints. Through a comprehensive analysis of absolute energy saving and relative energy saving rate from different time perspectives, the heating energy saving mechanism in lowering the heating temperature was discussed. We found two very different heating-saving mechanisms. Behavioral Energy Savings was dominated by heating time when the outside air temperature or accumulated indoor temperature was in the lower heating setpoint region, and Energy Savings Due to Temperature Difference. dominated the remaining heating time. If the building is used for different functions, the annual ESA is determined by the number of the above two types of heating hours, and the annual heating ESR is mainly determined by the heating hours when the heating demand is high [28].

Jong-Won Lee (November2020) measured and compared power consumption with and without the presence sensor and room management system in the university building's underground parking garage, auditorium, and dormitory to reduce the power consumption of university buildings. The underground car park and auditorium were surveyed during the semester while the sensors were being installed and removed. Since university classes are held every week, it is safe to assume that the number of cars and the access and usage of people are the same. The university's underground car park achieved a power savings of 39.5 Wh/(m2-day) per day, with a power savings rate of 77.6%. In the auditorium, these values were 25.0 Wh/(m2 day) or 32.4%. The amount saved when using the air conditioner was

55.0 Wh/(m2/day), and the saving rate was 27.9%. Dormitories use electrical energy for lighting, heating and sockets. 120 rooms were selected as a reference group and the room management system was applied to 10 random samples. In the dormitory, there was a power saving effect of 142.4 Wh/(m2day) per day, and the power saving rate was 28.2%. This study showed that the use of motion detectors and room management systems in university underground parking garages, auditoriums, and dormitories can save a significant amount of electrical energy [29].

3. Methodology

3. Methodology

3.1 Organizational part

The scientific project on turning Hochschule Nordhausen into a green university is being conducted by 10 teams. Each team has been assigned a specific task to contribute to the overall project.

The teams are organized as follows:

1. Data Acquisition Team: This team is responsible for collecting information about the campus, including the perimeter, area, number of buildings, number of parking stops, and number of bus stops.
2. Heat Energy Supply Team: This team is responsible for determining the heat demand and usage profile of the campus.
3. Electric Energy Supply Team: This team is responsible for determining the electricity demand and usage profile of the campus.
4. Potential Determination Team: This team is responsible for determining the renewable energy potential of the campus.
5. Transport Concept Team: This team is responsible for proposing transportation concepts that would reduce the CO_2 emissions on the campus.
6. Economic Analysis Team: This team is responsible for analyzing the cost of proposed solutions.
7. Sustainability Team: This team is responsible for analyzing the sustainability of the proposed solutions.
8. Saving Options Team: This team is responsible for determining ways to save heat and electricity on the campus.
9. Media Preparation Team: This team is responsible for preparing the media and graphics needed for presentations and reports.
10. Documentation Team: This team is responsible for documenting the scientific paper, along with the Media Preparation Team.

3.2 Data collection methods

Data collection is the act of obtaining and examining precise data from a variety of sources to identify solutions to study problems, trends, probabilities, etc., and to assess potential consequences. The researchers must specify the data sources, data types, and methodologies used during data gathering.

An analyst must initially provide three answers before they start gathering data:

What is the aim or reason behind this study?
What types of data are they going to collect?

What techniques and policies will be applied together, store, and process the data? [32].

1. Observation:

- The simplest approach is often the best. The process of acquiring information by keeping an eye on people, things, or things themselves in their natural environment is called ‘Observation method’ [33].
- Quantitative observation approach was used to determine the number of cars and people visiting the university campus during the whole day.

2. Face-to-Face interviews:

- Face-to-face interview is a data collection method where, the interviewer speaks with the respondent directly, uses a predetermined interview technique and questionnaire, and records the participants' responses using a predecided set of standard responses [34].
- Approximately 25 persons were interviewed about the frequency of their visits by the car, distance covered to travel the university, time taken by an individual to reach the campus as well as if they do car-sharing with any of co-student and so on.

3. Internet based research method:

- Internet-based research methods are any research techniques that use the Internet to collect data. Most frequently, the study has been carried out through the Web [35].
- Solar Rechner and google maps were used to determine the roof area of all the buildings along with the amount of radiation captured on the top of the building.
- Also, the number of buildings and rooms on the campus, together with information on how much area each building and individual room occupy, were derived from the website of Hochschule Nordhausen.

4. Assumption method:

- The term "Assumption Method" refers to the process of assuming the necessary data based on the data already available or other pre-defined strategy.
- On the basis of a prior project that was completed at the institution, load profiles for heat and electricity were assumed.

3.2.1 Campus Overview

- To collect data easily, the HSN campus plan is divided into two parts (Weinerghof and Helmestraβe) as shown in the below figure. In the campus plan, blue shows buildings, green shows open fields and white shows parking places. Accurate location in the campus plan can be seen in the figure.

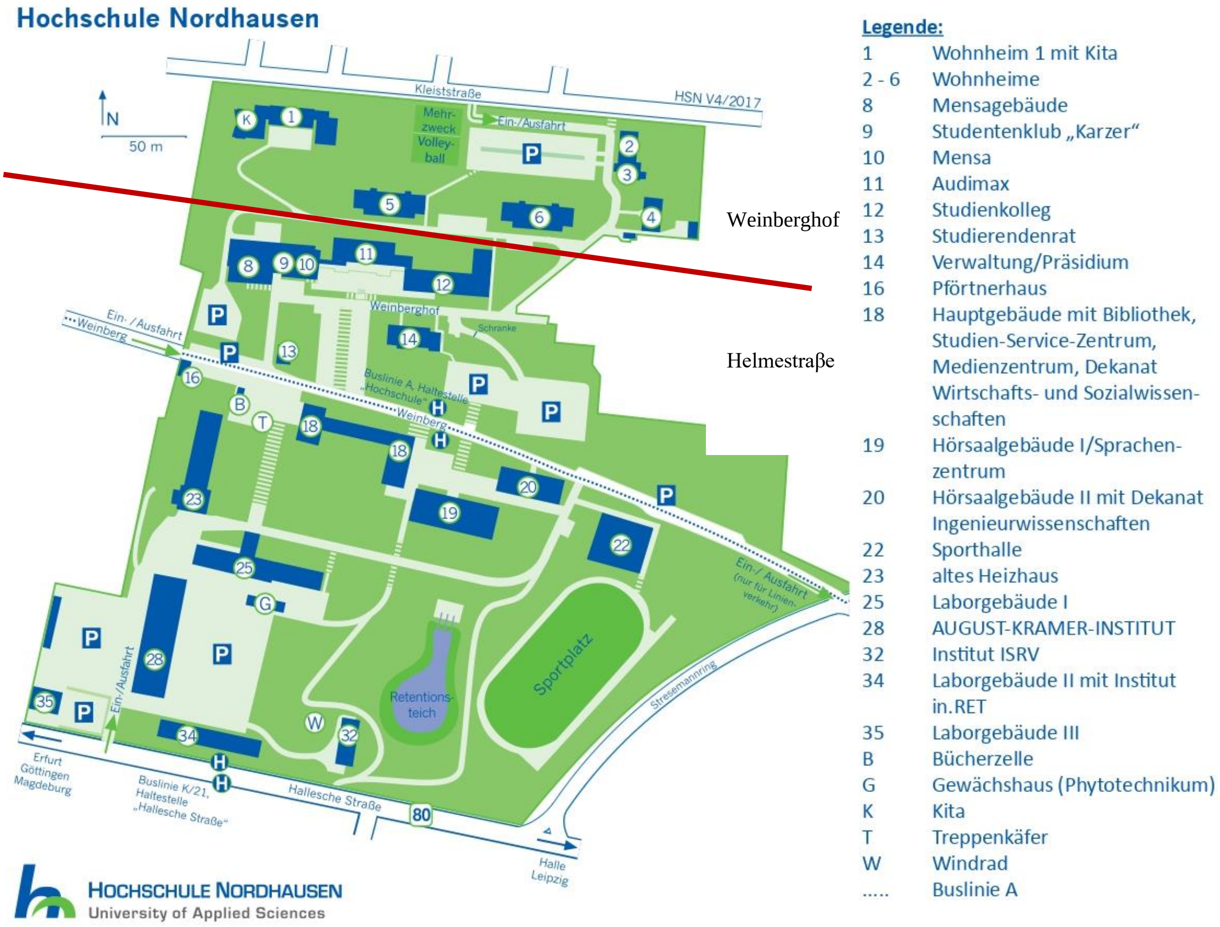

Figure 1 Campus Plan

- Building number 5 and 5a as shown in table below consists of 3 and 4 floors respectively. The total number of rooms in both buildings count as 22 bedrooms, 18 kitchens and 18 washrooms.

Table 1 Building 5 and 5a

Building No.	Floor	Bedroom	Kitchen	Washroom
5	1st	5	3	3
	2nd	2	2	2
	3rd	3	3	3
5a	1st	4	3	3
	2nd	2	2	2
	3rd	3	3	3
	4th	3	2	2

Figure 2 Building 5 and 5A

- Building number 6 and 6a as shown in table below consists 5 floors individually. The total number of rooms in Both buildings count as 69 bedrooms , 18 kitchens and 22 washrooms.

Table 2 Floor wise data building number 6 and 6a

Building No.	Floor	Bedroom	Kitchen	Washroom
6	1st	6	2	2
	2nd	9	2	3
	3rd	10	2	3
	4th	8	2	3
	5th	2	1	1
6a	1st	6	2	2
	2nd	9	2	3
	3rd	10	2	3
	4th	8	2	3
	5th	1	1	1

Figure 3 Building 6 and 6a

- Building number 7 as shown in the table below consist of 3 floors. The total number of rooms in this building is as follows 39 bedrooms, 16 kitchens and 10 washrooms.

Table 3 Floor wise data building number 7

Building No.	Floor	Bedroom	Kitchen	Washroom
7	1st	5	-	2
	2nd	17	8	4
	3rd	17	8	4

Figure 4 Building 7

- Building number 13 as shown in the table below consists of 3 floors. The total number of rooms in this building is as follows 14 bedrooms, 5 kitchens and washrooms

Table 4 Floor wise data building number 13

Building No.	Floor	Bedroom	Kitchen	Washroom
13	1st	6	2	2
	2nd	6	2	2
	3rd	2	1	1

Figure 5 Building 13

- Building number 14 and 14a as shown in the table below consists of 2 and 3 floors respectively. The total number of rooms in the building are as follows 21 bedrooms, 7 washroom and kitchens.

Table 5 Floor wise data building number 14 and 14a

Building No.	Floor	Bedroom	Kitchen	Washroom
14	1^{st}	7	2	2
	2^{nd}	7	2	2
14a	1^{st}	4	1	1
	2^{nd}	3	1	1
	3^{rd}	2	1	1

Figure 6 Building 14 and 14A

3.2.2 Additional PV area of campus

Figure 7 Possible PV Area

To maximize the PV potential, we have to search for additional areas which we can use to increase renewable energy production by PV. Our campus has 13 garages near building 35 in the true south direction without any direct shadows. This area is suitable for PV. The total area for the garages is 257 m^2.

In addition, we have 5 car parking spaces on our campus. The location of this car parking is in front of building number 34, 35, & 18 and beside the president building and weinberghof 14 & 14a. Due to some orientation and shadow effects of trees, we cannot use the parking slot in front of building number 34 and beside the president buildings. We are considering two parking areas near building number 35 and in front of Weinberghof 14 & 14a. We can utilize the 2218 m^2 area for the PV from these car parking areas. Here is a brief description of these car parking areas.

- In front of building number 18

In front of the library, there are three different free areas bus stops, bicycle parking, and car parking. We can use a total of 491m^2 of area for the solar-shaded parking.

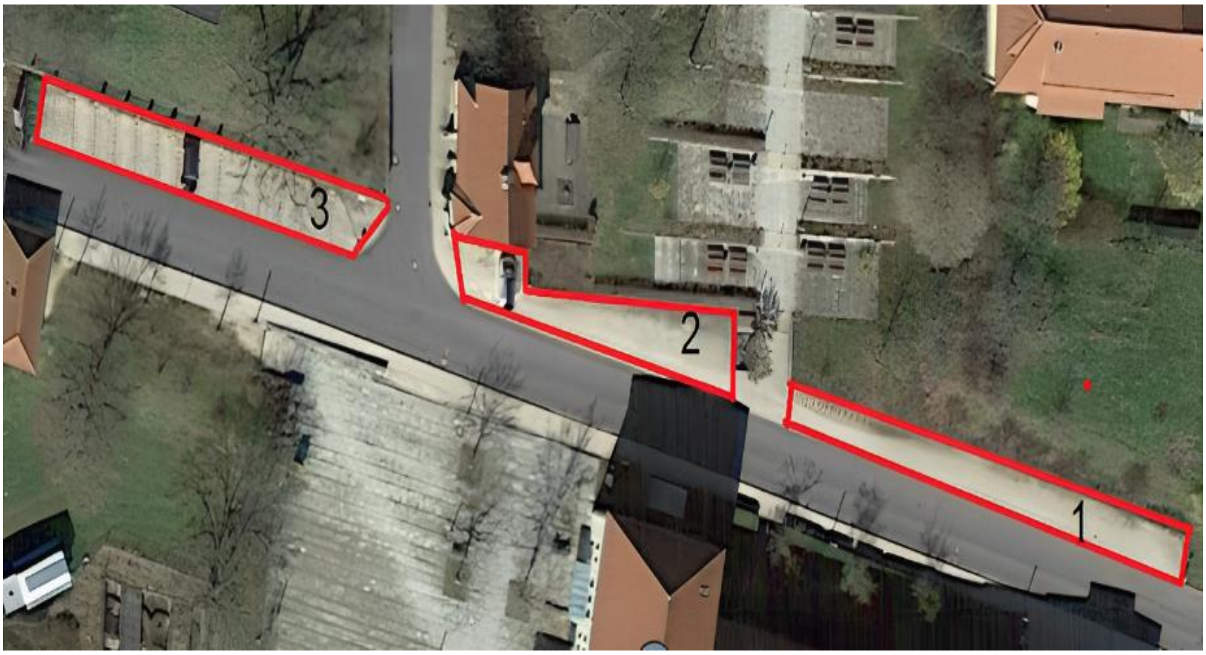

Figure 8 Parking in Front of Building 18

Table 6 Area of Parking

No	Capacity	Area in m^2
1	Bus stop	163
2	Bicycle Parking	141
3	14	187

- In front of building number 35

In front of building number 35 and beside the building AKI University has car parking. The parking lot's capacity is 96 cars and we can use a total of 1145 m^2 area for the solar-shaded parking.

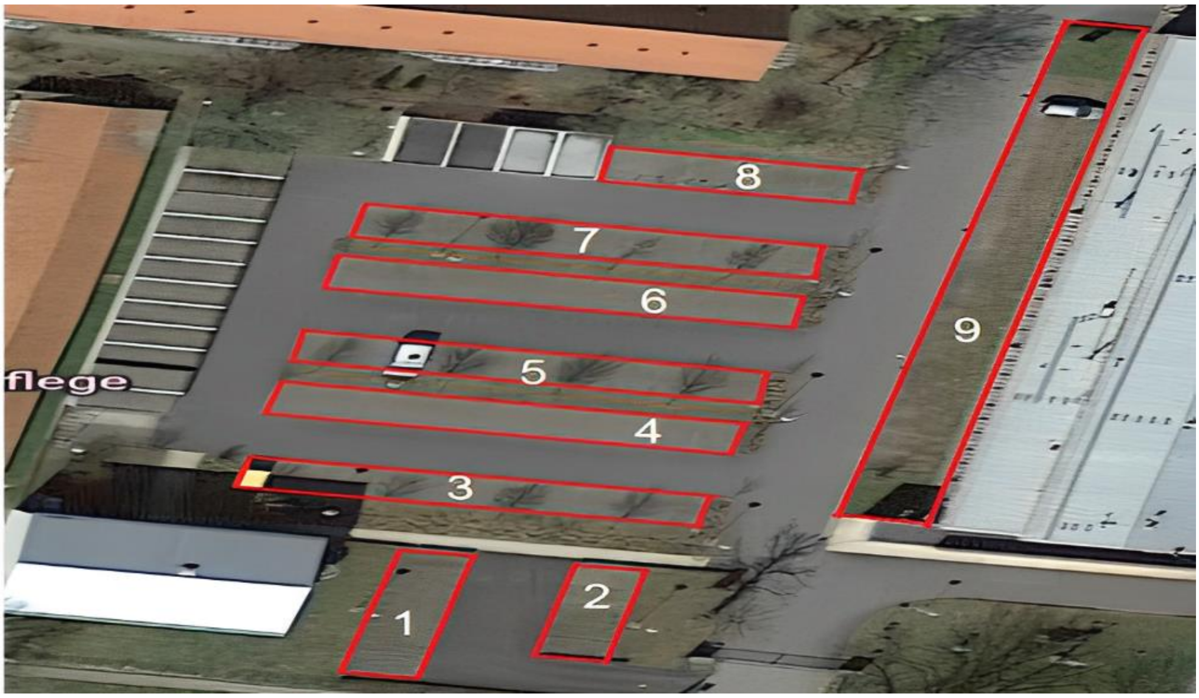

Figure 9 Parking in Front of Buildiung 35

Table 7 Area in front of Building 35

No	Capacity	Area m^2
1	7	85
2	4	55
3	11	128
4	11	128
5	11	128
6	11	128
7	11	128
8	6	65
9	22	300

- In front of Weinberghof 6 and 6a

Near to Weinberghof 6 & 6a university has 3 different locations for bicycle parking and dustbin. We can use a total of 160m^2 of area for the solar-shaded parking.

Figure 10 Free Parking Space Building 6 and 6a

Table 8 Area of Parking

No	Capacity	Area in m^2
1	Dustbin	50
2	Bicycle Parking	24
3	5	86

- In front of building 14 and 14a

In front of building numbers 14 & 14a, we have 4 different parking slots for the car. The total capacity of the parking is 48 cars and we can use a total of 1041m^2 of area for the solar-shaded parking.

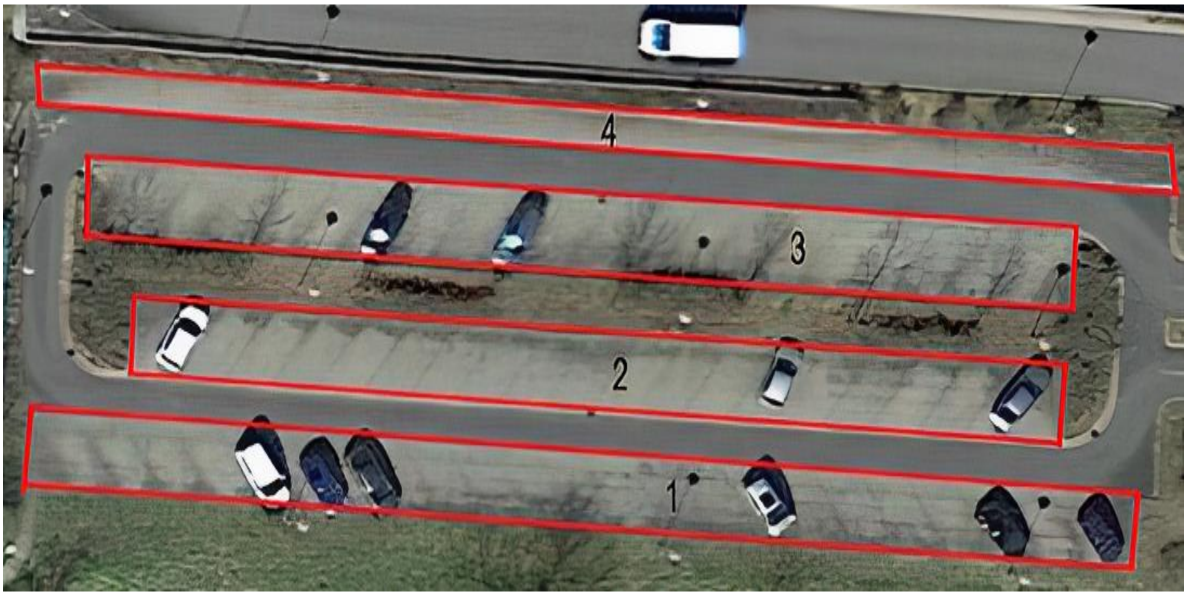

Figure 11 In front of Weinberghof 14 & 14ab

Table 9 Area in front of Building 14 and 14a

No	Capacity	Area in m^2
1	16	308
2	14	280
3	18	280
4	-	173

3.3 Study Design of Heat Demand Supply

To calculate the heat demand the following factors are considered

- Heat Losses
- Time period
- Data of heating space volume (Height, Area)
- Number and Area of Ventilations (Windows/Doors)
- Temperature Difference by Considering weather data

Firstly, the losses considered while calculating heat losses are transmission heat losses, heat transfer through wall, heat transfer through roof, heat transfer through floor, Ventilation heat losses and

Air infiltration. Because of number of buildings within the campus only specified buildings data with respect to year of construction, type of use (lab/office/living) and according to its perimeter are considered. Buildings taken into consideration are Building 34 (Office), Building 28 (old constructed lab), Building 19 (Newly constructed), Weinberghof 7 (Living).

Furthermore, to calculate the heat losses due to ventilation systems the number of buildings and its doors and windows are considered and with coefficient of conductivity.

Essential goals in the energy sector to make our university green may include providing low-carbon emissions, increasing the share of renewables, and maintaining relatively higher efficiencies in the energy utilization field. A heat load calculation plays an important role in achieving these goals by determining the amount of energy consumed on our university campus. The objective of the heat energy supply is to calculate the heat demand based on the load profile of the campus of the institution. Data collection from each building is part of the adopted approach in buildings 34,28,19, and 7. Data survey was collected for each building parameters such as window type, door type, building geometry, and types of insulation materials currently used in existing buildings. These data serve as input in modeling and calculating the head demand for both domestic hot water supply and space heating of the university campus. Furthermore, the thermal study of the building was recorded, which aids in measuring the building's energy efficiency. This analysis indicates which materials should be used to insulate heating devices and building parameters to reduce heat losses, energy demand, and space heating requirements. Several tools, including Python, Excel, and mathematical models, were used for modeling and heat load calculation using weather data throughout the year. In this work, heat load calculations were performed on four university buildings: buildings 34, 28, 19, and 7, which will later be scaled across the university campus. Prospectively, The Python code for calculation and results has been uploaded on the open-source platform GitHub for future access and continuous integration, and the results of this work should serve as a foundation for future heat energy-related measures at Hochschule Nordhausen [36].

3.3.1 Thermodynamic and Heat Transfer

The simple theory which is know from experience shows that a cold object (canned drink) left in a room will warm up and also a warm (canned drink) left in a cooling system (refrigerator) cools down. This is explained based on the transfer of energy from the warm medium to the cold one. Energy transfer is always from a region of higher temperature level to the lower temperature level, and the energy transfer stops when the two mediums reach the same temperature (equilibrium). From the principle of thermodynamics, energy exists in various forms. In this chapter, we are particularly interested in heat, which indicate the form of energy that can be transferred from one body to another as a result of change in temperature. The study that deals with the determination of the rates of such energy transfers is the heat transfer. The study of thermodynamic shows how much heat must be transferred to reach a specified change of state to justify the conservation of energy principle. In engineering the focus is more about the rate of heat transfer (heat transfer per unit time) than the amount of heat. For example, the amount of heat transfer can be determined from a thermos bottle as the hot coffee inside cools down from 90°C to 80°C by a thermodynamic analysis alone [30].

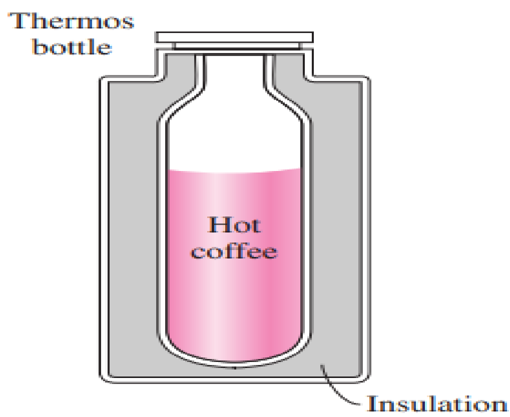

FIGURE 1–1
We are normally interested in how long it takes for the hot coffee in a thermos to cool to a certain temperature, which cannot be determined from a thermodynamic analysis alone.

Figure 12 Heat transfer[68]

But a typical user or designer of a thermos is primarily interested in how long it will last before the hot coffee inside bottle cools down to 80°C, and a thermodynamic analysis cannot answer this question. The determination of the rates of heat transfer to or from an object, including the time needed for cooling or heating, as well as the variation of the temperature, is the subject of heat transfer (Fig.11–12). The principle of thermodynamics deals with equilibrium states and changes from one equilibrium state to another. Whereas heat transfer, on the other hand, is concerned with systems that lack thermal equilibrium, hence classified as a nonequilibrium phenomenon.

This shows that, the study of heat transfer cannot be based on the principles of thermodynamics alone. But the laws of thermodynamics lay the framework for the science of heat transfer. The first law demands that the energy transfer rate into a system be equal to the rate of increase of the energy of that system. The second law tells that heat be transferred in the direction of decreasing temperature [30].

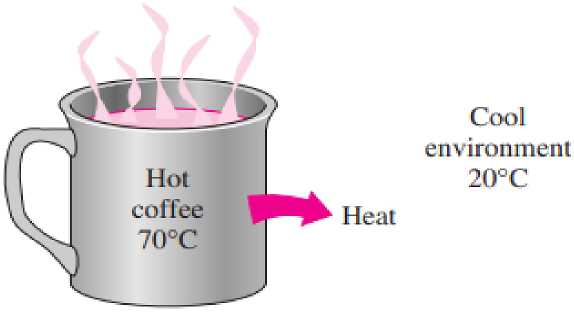

FIGURE 1–2
Heat flows in the direction of decreasing temperature.

Figure 13 Direction of heat flow[68]

It is like the electric current flowing in the direction of decreasing voltage or the fluid flowing in the direction of decreasing total pressure. The minimum or basic requirement for heat transfer is the presence of a temperature difference. The net heat transfer between two mediums of the same temperature always returns to be zero, which means no net net transfer can occur. It is therefore important to note that the driving force for heat transfer is the temperature difference, just as the potential difference is the driving force for electric current flow and pressure difference is the driving force for fluid flow.

3.3.2 Heat Transfer Equipment's

Some heat transfer equipment includes but not limited to the following:

1. Heat exchangers
2. Boilers
3. Condensers
4. Radiators, Heaters
5. Furnaces
6. Refrigerators and
7. Solar collectors designed primarily based on heat transfer analysis.

3.3.3 Application Area of Heat Transfer

Heat transfer is a major phenomenon which is always encountered in engineering systems including other areas of life, and the application of heat transfer occurs in different areas which is evidently seen around us or in the things we do. Very pronounced area of heat transfer is the human body, which is constantly rejecting heat to its surroundings, and human comfort is closely tied to the rate of this heat rejection [30]. We try to control this heat transfer rate by adjusting our clothing to the environmental conditions. Several household and building appliances are designed, in whole or in part, by adopting the principles of heat transfer. Underlisted here are examples of heat transfer which includes the electric or gas range, the heating and air-conditioning system, the refrigerator and freezer, the water heater, the iron, and even the computer, the TV, and the VCR. Of course, energy-efficient homes are designed based on minimizing heat loss in winter and heat gain in summer. Heat transfer plays a major role in the design of many other devices, such as car radiators, solar collectors, various components of power plants, and even spacecraft. The optimal insulation thickness in the walls and roofs of the houses, on hot water or steam pipes, or on water heaters is again determined based on a heat transfer analysis with economic consideration [30].

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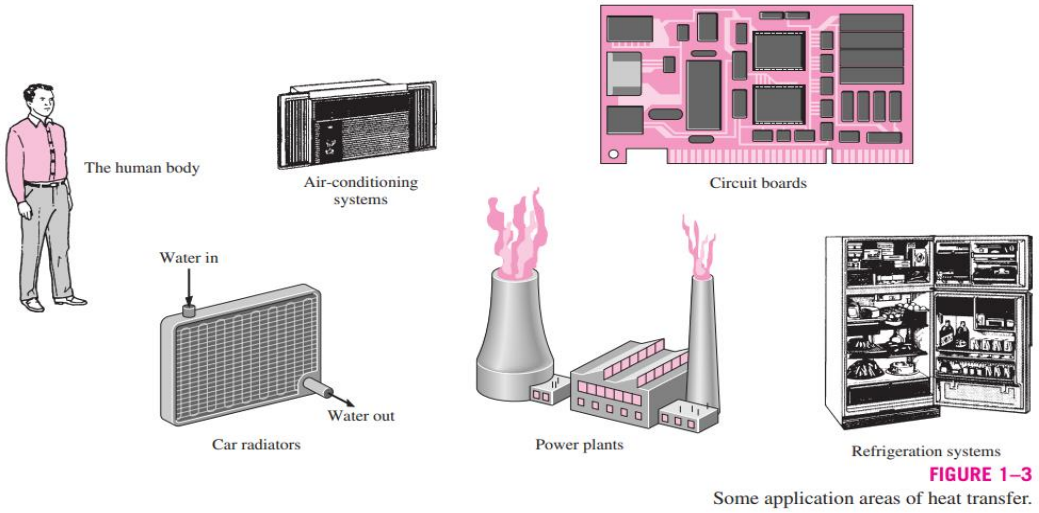

Figure 14 Application of Heat Transfer[68]

3.3.4 Considerations for heat demand supply

In 2021, about half of energy demand for buildings was used in space and water heating leading to about 2450Mt of CO2 emissions [37]. Considering the heating supply to Hochschule Nordhausen, All data necessary for the modelling and determination for the heating supplies has been properly collected considering both old and new building as well as the insulation capacity for selected buildings has been put into considerations. For space heating and DHW (Domestic Hot water) demand, python tools have been used for sizing the demand and modelling for efficient analysis. Suggested types of insulation for building and economic analysis was also considered.

- Thermal study

A thermal study of a building aims to measure the energy efficiency of a building to be built or already built. It intervenes in renovation or new construction. This analysis gives keys to the materials to be used for the insulation or installation of a heating device.

- Conductivity

The thermal conductivity of a material is a measure of its ability to conduct heat. It is commonly denoted by: k. Heat transfer occurs at a lower rate in materials of low thermal conductivity than in materials of high thermal conductivity. Here as we can see these are the different conductivity of construction materials [38].

Table 10 Building Material and density

No	Building Material	Density(kg/m^3)	K(W/m.K)
1	Concrete	2.400	1,448
2	Aerated Concrete	960	0,303
3	Plastered Clay Brick	1.760	0,807
4	Exposed Clay Brick	-	1,154
5	Glass	2.512	1,053
6	Gypsum Board	880	0,170
7	Steel	7.840	47.6
8	Granite	2.640	2,927
9	Marble/Ceramic/Terazzo	2.640	1,298

We are going to work on classroom of building 34.Hochschule Nordhausen:

Figure 15 Building 34

Here we take out the different measurements of the room:

We will focus on the study of walls, windows and roofs:

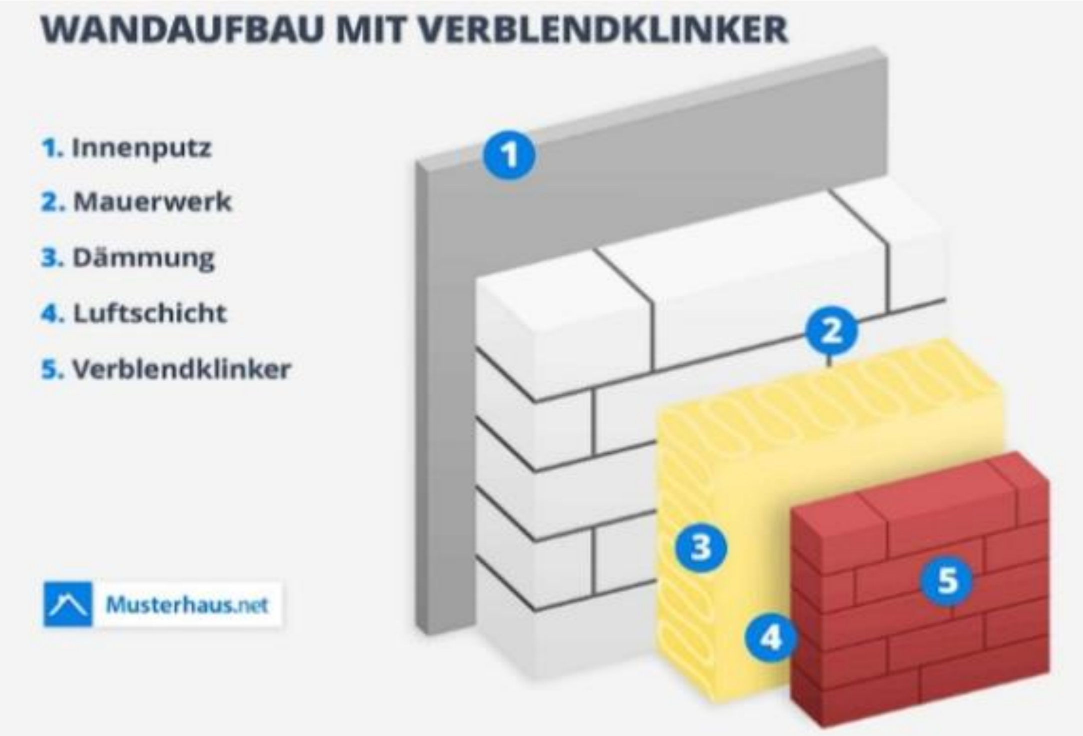

Figure 16 Types of Walls

Material Used in Construction

Table 11 Materials Used

Material used	Thickness	Conductivity(W.m/K)	Resistance(m^2.K.W^{-1})
Inner plaster	0,1	-	0,13
Brickwork	0,19	0,99	0,1919191919
Insulation	0,19	0,035	5,428571429
Blinding clinker brick	0,1	1,1	0,09090909091
Exterior plaster	0,1	-	
Double Glazing	-		

Table 12 Further Details of Material

Element	Coefficient U(W/m^{2}K)
Double Glazing	2,800
Wall	0,167
Roof	1,950

Table 13 Loss by Transmission Through the Walls

Orientation of the walls	Surface(m^2)	Coefficient U(W/m^{2}K)	Difference of Temperature between inside and outside(Winter, Celcius)	Winter losses (W)
West wall	30,24	0,167	27	136,732
South wall	35,521	0,167	27	962,064
East wall	22,176	0,167	27	598,752
North wall	30,648	0,167	27	827,496
West double glazing	0	2,800	27	0,000
North double glazing	10,752	2,800	27	290,304
South double glazing	5,768	2,800	27	436,061
East double glazing	8,064	2,800	27	609,638
Roof	96,9	1,950	27	5085,990
Total				5695,628

The thermal resistance R (in m^2. K/W) depends on the thickness (e expressed in meters) and the thermal conductivity (λ) of the material: [39]

$$R = \frac{e}{\lambda}$$

$$r_g = \frac{1}{h_e} + \frac{1}{h_i} + \Sigma r_j + \Sigma(\frac{e}{\lambda})j$$

The heat transfer coefficient, abbreviated as “U coefficient”, makes it possible to quantify the thermal losses of an insulating material. More concretely, this coefficient indicates the quantity of heat which passes through a wall, i.e. the capacity of the wall to let the heat escape [39].

$$U = \frac{1}{r_g}$$

1.Windows

Figure 17 Cross-Section of Window

Double glazing reduces heat loss through windows by at least 40% compared to single glazing. Insulation is measured by the U_g coefficient. The U_g value of single glazing is 6.8 while that of double glazing is 2.8.

Air is a very good insulator, especially when it is still. However, some gasses perform even better. This is the case, for example, of Argon (or krypton), which is the reference today. The performance is not radically improved (5 to 20% of the total performance of the glass including the chassis), but the additional cost is very low.

compared to the windows of the building (HAUS 34) they are already double glazed, so we will not make any thermal improvement.

2.The Roof:

Insulating your roof is an effective way to improve thermal comfort in your home and reduce your energy bills. Indeed, the roof is responsible for approximately 30% of heat loss1. Insulating the roof is therefore essential, and can be done using many techniques.

Which insulation to choose?

Two criteria can be useful to help you analyze the performance of an insulator. These are thermal conductivity and thermal resistance

As for thermal resistance, it is the ability to resist hot and cold. The higher the coefficient, the more insulating the material. To insulate the roof, there are therefore many materials of synthetic, mineral or vegetable origin. Natural insulators deserve to be known, because they have many advantages.

Vegetable wool: Vegetable wool insulation is an excellent substitute for synthetic materials. It is made from natural products such as straw, hemp, cotton, wood, coconut fiber or even flax.

Easy to install, non-toxic and environmentally friendly, vegetable wool offers excellent thermal and acoustic comfort.

Figure 18 Roof Insulation

Cellulose wadding: Cellulose wadding is made from recycled paper. It is treated to be non-flammable and resistant to pests. This type of insulation is the most used in wooden constructions and new buildings with low consumption.

Cellulose wadding has a high insulating power and comes in different forms: in bulk, in compacted or uncompacted form, or even in panels.

Figure 19 Cellulose Wadding

The cork : Ecological, efficient, healthy and natural, cork is an excellent roof insulator. It offers both thermal and sound insulation, and does not need to be treated to resist insects or rodents, unlike other natural insulators. It is also naturally waterproof and fire resistant. Its high resistance gives it a long life.

- What thickness of insulation for the roof?

The thickness of the insulation is a key point for good roof insulation. If you opt for vegetable wool, choose a thickness of 14 to 18 cm. For cellulose wadding, it is recommended to lay a thickness of about 25 cm.

Finally, the cork can be laid to a thickness of about 25 cm: if necessary, two panels can be installed, one on top of the other.

RT 2020 aims to impose on developers the construction of positive energy buildings in addition to passive houses.

- Wall insulation

Thermal insulation of walls from the outside has more advantages than insulation from the inside. It is therefore to be preferred because it greatly limits thermal bridges, contributes significantly to summer comfort and better protects the building from hygrothermal risks. However, its implementation proves impossible in certain cases, in particular in classified areas.

Conversely, the interior insulation will be relevant if the exterior appearance of the facades cannot be modified, if the interior facings need to be renovated or if the living space must be restructured.

It is quite possible to combine the two processes if the connections between the different facades are well treated.

And these are examples of insulators materials than can be used with their different conductivity coefficients [40]

Figure 20 Straw (0.05m/microkelvin) [69]

Figure 21 Wood Wool (0.04m/microkelvin)

Figure 22 Rock Wool (0.039m/microkelvin)

Figure 23 Glass Wool (0.035m/microkelvin)

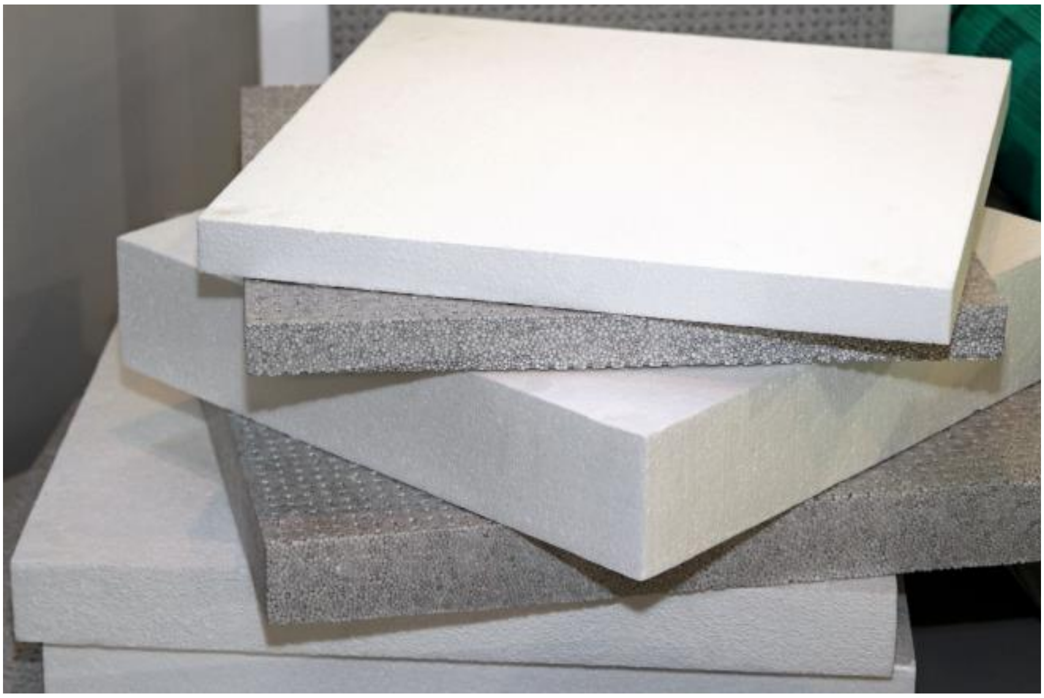

Figure 24 Polystyrene (0.034m/m/microkelvin)

- Costs of insulation materials

Figure 25 Sonorock partition wall panel

Rockwool Sonorock partition wall panel 60mm 5,625m² **Price: 54,35€** (9,90€ / Quadratmeter) [41]**.**

Figure 26 Isover lamellar mat ML 3 aluminium laminated 30 mm

Isover lamellar mat ML 3 aluminium laminated 30 mm = 40,75€ (8,49€ / Quadratmeter) [42].

Figure 27 Isoler 7822720 Integra ZKF 1-035 200mm

Isoler 7822720 Integra ZKF 1-035 200mm (26,88€ / quadratmeter) [43]

According to the prices we saw here , the best choice we can offer in our insulation correction to the wal4ls is Isover lamellar mat ML 3 aluminium laminated with a (8,49€ / quadratmeter).

3.4 Electrical Energy Methodology

The main objective is to the annual energy consumption of the university. This needs to be identified to determine the potential power generation requirements within the university. The methodology for the estimation of electrical energy consumption and demand uses the data from both the above-mentioned works of literature. Numerous considerations were made to achieve the calculations and results as relevant as they could be for the betterment of the project. The data used and considerations made during the calculation part are described in the following points,

- The average annual electrical energy consumption for the university in the years 2011 to 2013 was 1173 MWh [72].
- The calculation model for area-specific energy consumption was considered with North Campus and South Campus as shown in fig.58 for the ease of calculations similar to that of work done by Balasoltanov etal. worl. The calculated average area-specific consumption for the campus is as follows:
    - For North Campus: 655,509 kWh/a
    - For South Campus: 197,579 kWh/a
    - Total calculated consumption (Balance area): 853,088 kWh/a
    - The area-specific consumption adds to 853,088 kWh/a which is far less than 1173 MWh/a. The difference in consumption is 320,753 kWh/a.

The difference in this energy consumption is first determined based on the buildings for which the energy consumption was not considered. The buildings identified as present-day buildings 9, 10, Weinberghof 7/7a, Weinberghof 13 and Weinberghof 14/14a from North Campus The above-mentioned consumption difference is the average annual consumption of these buildings. Since building 32 from South Campus was being constructed during the years 2011 to 2013, the energy consumption calculations were not possible for this building.

The identified buildings are categorized into student apartments and university buildings. The total area of all the buildings is obtained from the Data acquisition team and Google Earth to get an approximate value for the energy consumption per unit area (Energy indicator value). This value is calculated from the buildings where the internal readings were performed by Balasoltanov etal. worl. The calculated value is used to find the average annual energy consumption of the building whose internal readings were not previously performed.

- Since energy consumption data for building 32 is not available, an approximate value is added to the 1173 MWh/a getting a new value of 1200 MWh/a.
- Standard load profile for electric supply of commercial sites [73] is distributed with respect to the available data from 2011-2013 to get a relevant figure/data for energy consumption of the University.
- The building-specific electricity consumption along with the percentage share of each building for each region [72] and for the whole university was calculated for the new annual electricity consumption of 1200 MWh.

Figure 28 Subdivisions of University [72]

3.5 Study Design of Potential Determination

3.5.1 Photovoltaic Potential

PV was the most optimal choice for our campus-
The location determines which orientation is ideal for solar panels. Solar installations in the Southern Hemisphere should be put north, whilst those in the Northern Hemisphere should be installed south. The sun has a northern offset in the southern hemisphere and a southern offset in the northern hemisphere, which causes this ("The Best Direction for Solar Panels | Roofit. Solar". As a result, because Germany is located in the northern hemisphere of the globe, photovoltaic or solar thermal panels should be oriented southward.
Our campus has a great deal of potential for using solar power to meet our electricity and heating needs. This assertion can be supported by the graphs provided below. Furthermore, for this primary reason, we regarded solar technology as the most optimal and efficient renewable energy technology for our campus.

As shown in fig below, our campus has many south-facing buildings, such as Weinberghof 7, Weinberghof 14, in.RET building, and so on. Furthermore, the Weinberghof 7 building has the most roofs facing south, making it one of the best buildings for PV panel installation as per the direction. However, due to other factors such as roof tilt, shadow effect, and complexity of roof designs, this building falls short of the top spot.

On the other hand, there are other buildings with roofs that do not completely face south but perform better in other aspects such as irradiance value and shadowing effect, making them a better choice for several solar technologies.

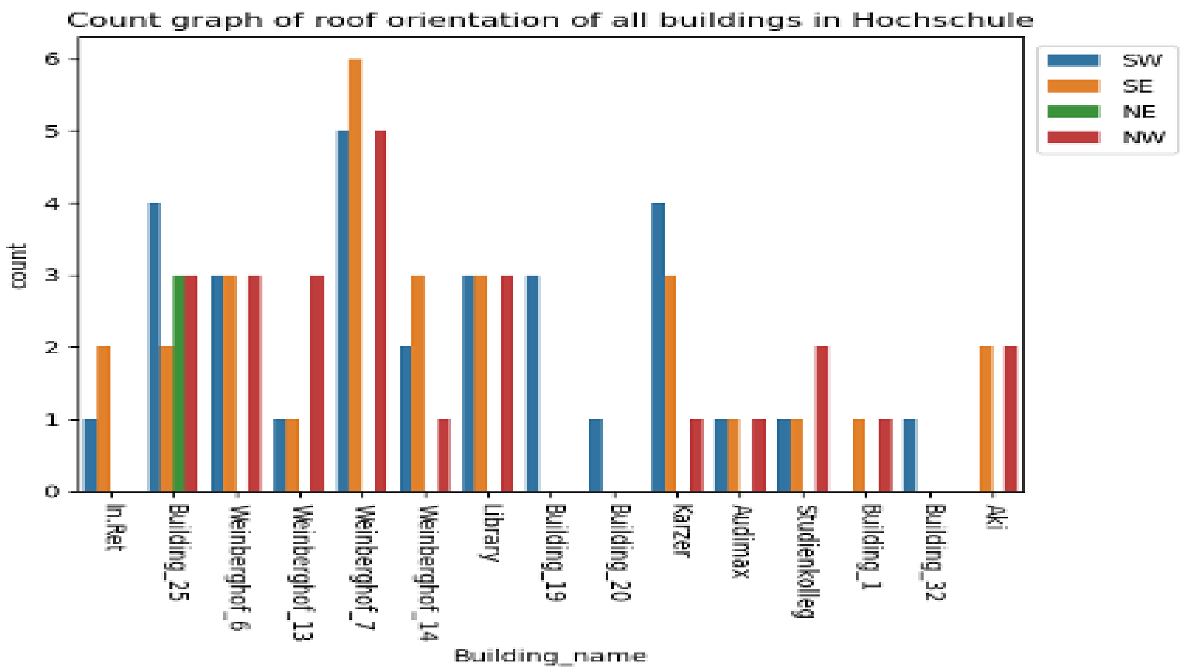

Figure 29 Graphical Representation of Number of Roofs And Buildings In The Campus

Based on parameters such as total irradiance, shading effects, building orientation, and roof complexity, our group produced a result that shows the most optimal, good enough, and not recommended buildings for PV system installation. The overall findings are depicted in the figure below.

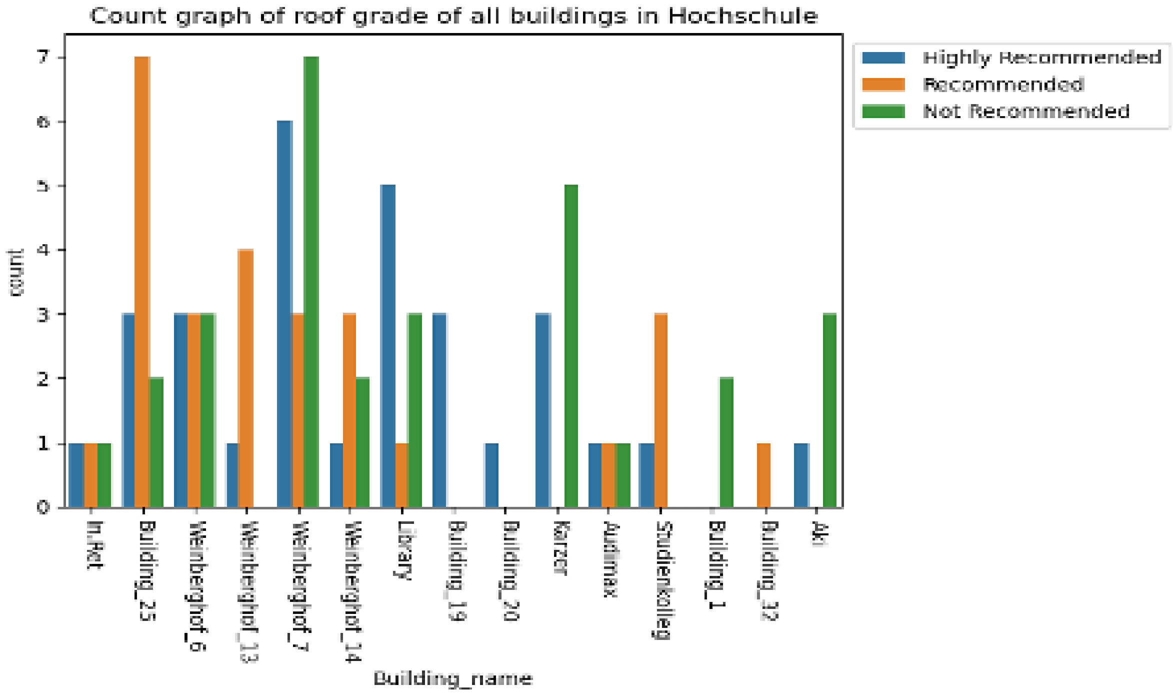

Figure 30 Graphical Representation of Performance of Various Buildings

The above figure shows that building 25 is the most recommended building to install a PV system because the orientation is south facing, there are no objects around the building that would cast shadows on the PV panel, and the most important factor is that the irradiance that falls on this particular building is the highest, making building 25 the most optimal building to install various solar technologies.

- Software Consideration for Photovoltaic

Pvlib python is a community-supported tool that helps to simulate the performance of a photovoltaic system by providing a set of functions and classes. The package aims to provide an instance of models relevant to solar energy, including algorithms for solar position, clear sky irradiance, irradiance transposition, DC power, and DC-to-AC power conversion. pvlib was developed at Sandia National Laboratories as a MATLAB tool in the year 2014 and was later ported as a python tool in the year 2015. The package works with API designed to cater the various requirements of the several subfields of solar power research and engineering. The API's are carried out in three layers: core functions, Location and PVSystem classes and the Model Chain class [44].

The ModelChain function requires two main arguments which are location and system. The location requires the user to feed in values of latitude, longitude, time zone, and altitude to create the location argument and the system function requires, tilt angle, azimuth angle, the type and manufacturer of the PV module and an inverter which consists of spec sheet data, temperature model, modules per string, and the number of strings. Once this has been done, irradiation data is required. The package is able to provide the irradiation data but this is not very accurate as it does not consider POA (plane of array). POA is the best way to calculate the energy output of the PV system as it considers irradiation affected due to the tilt of the PV array. To do a POA analysis we use the irradiation data from PVGIS. PVGIS is a website created by the European Commission that provides information about solar radiation for any location in Europe, Africa, and large parts of America and Asia [45]. The mpp is very important because all the appliances need to operate near the mpp to utilize all the electrical energy. On cloudy days or in some cases of roof mount PV systems it happens to be the case that there are multiple roofs with different tilt angles. In such scenarios, the mpp keeps shifting so it becomes necessary to track the mpp to draw out the maximum power of the panel. The mpp can be also be done on pvlib, the mpp function requires irradiation across the year, the temperature of the panel across the year, temperature coefficients, shunt resistance and series resistance.

- Complex roofs

  As we have discussed solar roofing for different buildings at Hochschule Nordhausen, we noticed that most of the buildings have complex roofs. For example, if we take a look at the roofs of buildings Weinberghof 6, Weinberghof 13, building 8, 9&10 these buildings have complex roof system, which makes the installation difficult and costly.

  So complex roofs are the biggest challenge, while exploring the possible solutions we thought, why don't we build our own roofs which are perfectly oriented in such a way that solar roofs capture most of the solar energy? The solution is constructing "Solar shaded parking spaces".

3.5.2 Consideration for Calculation

PV roof mount installation is very promising now an assessment of these roofs needs to be done by implementing some important PV roof mount parameters to generate maximum energy yield. The parameters are given points in order to find out the best five buildings on the campus. These parameters are:

- Area: The area should be as maximum as possible as this determines the size of the PV system. The more area the bigger the size of the installation you have.
- Irradiation: A minimum of 1000 kWh/m^2/a of irradiation is required for an economically viable system.
- Optimum direction = True south or azimuth of 180^0, for North Hemisphere. It is better to stay within plus or minus 20^0 of this value, anything more than this the PV system tends to drop efficiency.

- Optimum roof tilt = 30^0, for Germany but this parameter is not that important as the efficiency does not drop in huge margins like the orientation parameter.

Along with these, there is a special parameter for buildings with a flat roof which requires a mounting system to maintain a tilt. Such a building would receive negative points as now a tilted PV panel would give out shadows which could fall on the panels behind them so now a minimum distance will have to be maintained to prevent a shadow effect, this would thus reduce the area of installation.

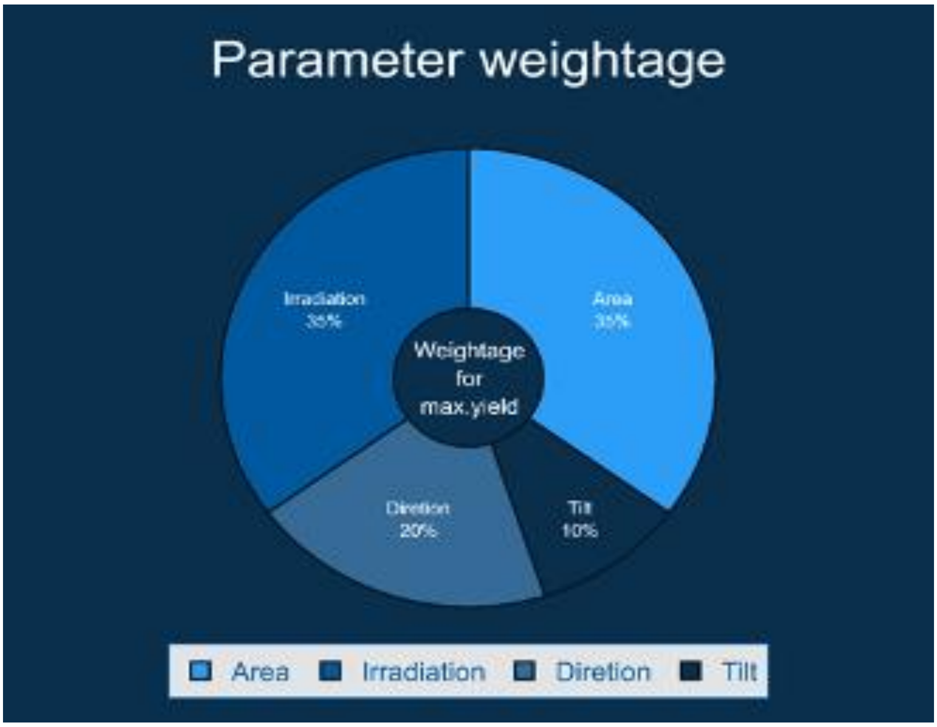

Figure 31 Parameter Weightage For PV Module

The following Buildings from the university campus are taken into consideration for the parameter weightage analysis:

1. Building 19
2. Building 20
3. AKI (Building 28)
4. in.RET (Building 34)
5. Studienkolleg (Building 12 Building 25,

Table 14 Total of building parameters

Para-meters	Building 19	Building 20	AKI	in.RET	Studien-kolleg	Building 25
Mounting System applicable	Yes	Yes	No	No	No	No
Roof area	25	19	23	17	15	26
Irradiation	30	31	31	32	35	34
Roof orientation	20	20	0	18	20	19
Roof tilt	0	0	2	10	10	5
Total	**75**	**70**	**58**	**77**	**80**	**84**

(*note: the grading system works on the principle of relative grading with Building 19 having the highest open area and the Studienkolleg receiving the highest irradiation)*

From the above table of results, the AKI building performs poorly and therefore is eliminated from being considered for further analysis.

Now that the buildings have been decided the next step would be to figure out how many panels can be fit on the selected roofs of these buildings. This has been done with the help of AutoCAD and Google Earth. A snip of an aerial view of all the buildings is taken and uploaded on AutoCAD then the images are scaled according to the dimensions of the roof which is done with the measuring tool available on Google Earth. Once the 2-D drawings are ready, the area can be easily calculated and is more accurate than the area given by the solar rechner.To do a panel layout a reference panel is required and this is taken from the pvlib database as this python package will be used to model the PV system to determine the electrical energy output. The reference PV panel chosen was Hanwha Q cells Q peak 370 watts and its properties are mentioned in the following table.

From the table below, the values of length and width are taken to create a replica on AutoCAD to perform a panel layout. The panel layout would not only give the exact number of panels that can be fit onto the roof, in fact, it also gives a visual representation of the panel layout. The panels are placed with an inch gap between them and below them. The first layer of the panels is placed half a meter below the ridge so that there is some place for the technicians to walk.

Table 15 Data Consideration

Technology	**Multi-c-Si**
Bifacial	0
STC	370.0012
PTC	340.6
A_c	1.946
Length	1.97
Width	0.988
N_s	72
$I_{sc,ref}$	9.89
$V_{oc,ref}$	48.28
$I_{mp,ref}$	9.41
$V_{mp,ref}$	39.32
α_{sc}	0.003758
β_{oc}	-0.139529
T_{NOCT}	45.5
a_{ref}	1.86472

$I_{L,ref}$	9.997571
$I_{o,ref}$	0.0
R_s	0.35409
$R_{sh,ref}$	407.904602
Adjust	8.079701
γ_r	-0.394

After the exact number of panels is derived, a suitable inverter is required to complete the system as appliances run on AC power and not on DC. The sizing ratio (SR) is a step taken to choose an appropriate inverter for the PV system. It is defined as the maximum DC power of the system divided by the AC power of the inverter

$$SR = \frac{P_{PV,STC}}{P_{inv,AC}}$$

The SR is affected by three factors: the size of the array, geographic location and site-specific conditions.

- Size of the array

  This is the most important factor in selecting the appropriate inverter. A general rule of thumb is to choose an inverter that is similar to the DC rating of the PV system.

- Geography

  Geography is also an important factor in determining a suitable inverter as all locations receive a different amount of solar irradiation. The locations near the equator have higher irradiations and locations near the poles have lower irradiations so a PV installation of the same size would perform much better at the equator than the system at the poles. As these two systems will produce different amounts of electricity at a given point in time, the inverters that handle the electricity load will also be different. An inverter rating close to the DC rating of the PV system can be considered for locations with higher irradiations and an inverter rating less than the DC rating can be considered for locations with lower irradiations.

- Specific site conditions

  Similar to the geography the azimuth and tilt angle are important factors that can affect the electricity production capacity of the solar array. Environmental factors such as shading due to clouds or obstacles, dust, and snow will also affect the sunlight reaching the panel. For the locations in the North Hemisphere, it is best to place the solar array at an azimuth angle of 180^0 or true south, similarly, for the South Hemisphere it is best to place the solar array at an azimuth angle of 0^0 or true north. Electricity production will reduce as you deviate from true south or true north for locations in North Hemisphere and South Hemisphere. The tilt angle is based on the latitude of the location and is therefore different for all locations. The tilt angle is not as important as the orientation factor and not able to achieve this will still give good results.

From the above three factors, the sizing ratio should be in the range of 0.83<SR<1.25, SR less than 1 is an oversized inverter and should only be considered in geographic locations that receive high irradiation. In general, it is a good practice to maintain the SR between 1.1-1.25. The PV system will not always generate power at its rated value so there is no point in considering an inverter close to its DC as this will be not economically viable.

After the SR is done string sizing needs to be done to determine the number of strings and panels per string to connect to the inverter. There are many methods to determine the number of panels in a series of strings but the best method is done by voltage dimensioning. To do this the max and minimum voltage of the inverter, temperature coefficients, open circuit voltage (V_{oc}), maximum operating voltage (MPP) of the panel and maximum and minimum temperatures of the environment. All these values are available on the module and inverter database in pvlib.

$$V_{oc\,(T)} = V_{oc,STC} \cdot [1 + \beta\,(T - T_{STC})]$$

$$N_{max} = V_{Inv,max} / V_{oc\,(T=min)}$$

$$N_{min} = V_{Inv,MPP(min)} / V_{MPP\,(T=max)}$$

The $V_{oc,Tmin}$ and $V_{mpp,Tmax}$ are calculated with the help of equation 1, the value of the N_{max} must be reduced to the previous whole number to prevent overloading the inverter and the value from N_{min} should be increased to the next whole number to provide minimum voltage to start the inverter.

Now that the panel layout and inverter sizing are done a virtual model can now be designed on pvlib and the energy production can be estimated. From the above table -24, it can be observed that some of the roofs have different tilts and orientations so MPP tracking is performed to draw out maximum power at best and worst conditions.

3.6 Available Parking Area

There are 5 parking spaces in total, which has a capacity of 440 car parking spaces.[65]

1. Viable parking spaces

After considering the sizes and shading effect of trees, we have short listed few parking lots. The following are most viable parking spaces available in Hochschule Nordhausen. These are two big parking lots available at the campus. One is opposite to Weinberghof 14 and the other one is behind August-Kramer-Institute [65].

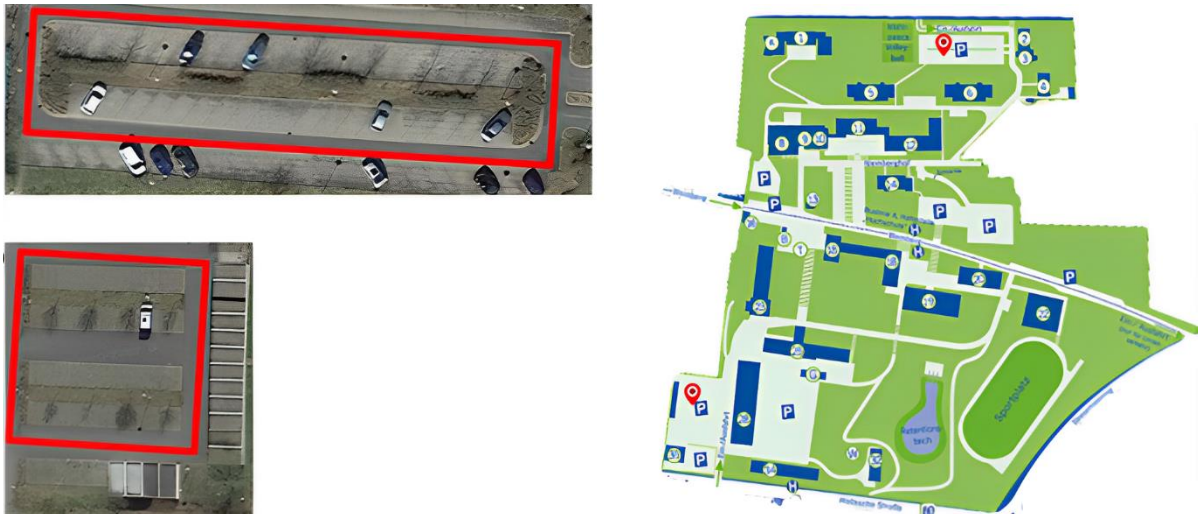

Figure 32 Viable Parking lots at Hochschule

2. Advantages of the selected parking lots
Solar-shaded parking at these parking lots offers numerous advantages for parking lots. They are, having a large area and good irradiation facing in the south direction with an optimum roof tilt. The south direction of the parking lot allows for maximum exposure to the sun, and the optimum roof tilt maximizes the efficiency of the photovoltaic panels. With its big area, good irradiation, and optimal orientation, solar-shaded parking at these parking lots is effective and sustainable solution for creating a greener and more energy-efficient campus.

3.6.1 Solar shaded parking

Solar-shaded parking spaces are parking areas that are covered or partially covered with photovoltaic panels to generate clean, renewable energy while providing shade for parked vehicles. These structures offer a solution to the challenges posed by traditional parking lots.
Solar-shaded parking lots have become an increasingly popular solution for creating green and sustainable campus environments. These structures offer numerous benefits that make them an ideal solution for reducing the environmental impact of parking areas and promoting a greener campus environment for Hochschule Nordhausen.
According to the German Federal Environment Agency, heat islands are "areas that are significantly warmer than their surrounding rural areas due to human activities, particularly in urban areas" [66](German Federal Environment Agency, 2018). Parking lots and other paved surfaces are particularly prone to heat-island effects, as they absorb large amounts of heat and contribute to higher temperatures in urban areas. By shading these areas with photovoltaic panels, it is possible to reduce the amount of heat absorbed by the pavement and reduce the overall temperature of the surrounding area. This not only makes the environment more pleasant for students, faculty and staff, but it also reduces the energy consumption associated with cooling and heating systems.

In addition to reducing heat-island effects, solar-shaded parking lots also have the potential to generate clean, renewable energy. In Germany, where sustainability is a top priority, universities like Hochschule Nordhausen are looking for ways to reduce their carbon footprint and demonstrate their commitment to the environment. According to a study by the German National Renewable Energy Agency, photovoltaic panels in parking lots can lead to significant reductions in energy consumption and carbon emissions, particularly in urban areas[67] (German National Renewable Energy Agency, 2016). This not only helps to reduce the overall environmental impact of the campus, but it also saves the university money on energy costs over time.

Another benefit of solar-shaded parking lots is that they provide shade for vehicles and protect them from the elements. This is especially important in hot, sunny climates, where temperatures inside a vehicle can become dangerously high, putting drivers and passengers at risk. By shading vehicles with photovoltaic panels, it is possible to reduce the amount of heat absorbed by the interior of the vehicle, making it much more comfortable for drivers and passengers. It also saves the energy required for air conditioning. In winter if the car is parked under a solar-shaded parking roof it also prevents snow on the windshield of the car, this, in turn, helps the driver by reducing his work of clearing the snow, before going for the drive.

Finally, solar-shaded parking lots are cost-effective, as they reduce the need for additional cooling and heating systems, which can be expensive to install and operate. In addition, by generating clean, renewable energy, they reduce the amount of energy that needs to be purchased from the grid, which can result in significant cost savings over time.

In conclusion, solar-shaded parking lots are an excellent solution for creating a green and sustainable campus environment at Hochschule Nordhausen. By reducing heat-island effects, generating clean energy, providing shade for vehicles, and reducing energy costs, these structures offer numerous benefits that make them an ideal solution for creating a more environmentally friendly campus. By implementing solar-shaded parking lots, Hochschule Nordhausen can demonstrate its commitment to sustainability and make its campus a more enjoyable place to study and work

3.7 Aeromine technologies

3.7.1 Comparing wind speeds and wind directions for feasibility of wind rooftop technology

1. Wind Roses Using Autodesk Format Software for Location Building 19 & 20 (Wind Speed & Wind Direction):

The wind rose graphically conveys the probability of data for each of the 12 wind directions. Wind direction measurements provide information on how frequently the wind blows from each of the 12 directions. These four wind roses were created using Autodesk Format and the nearest four weather stations, which reflect the majority of data yields in the south-west direction, which is identical to the wind direction results from the Python tool. According to the results of both Python and wind roses, the dominant direction of the wind is most likely in the southwest.

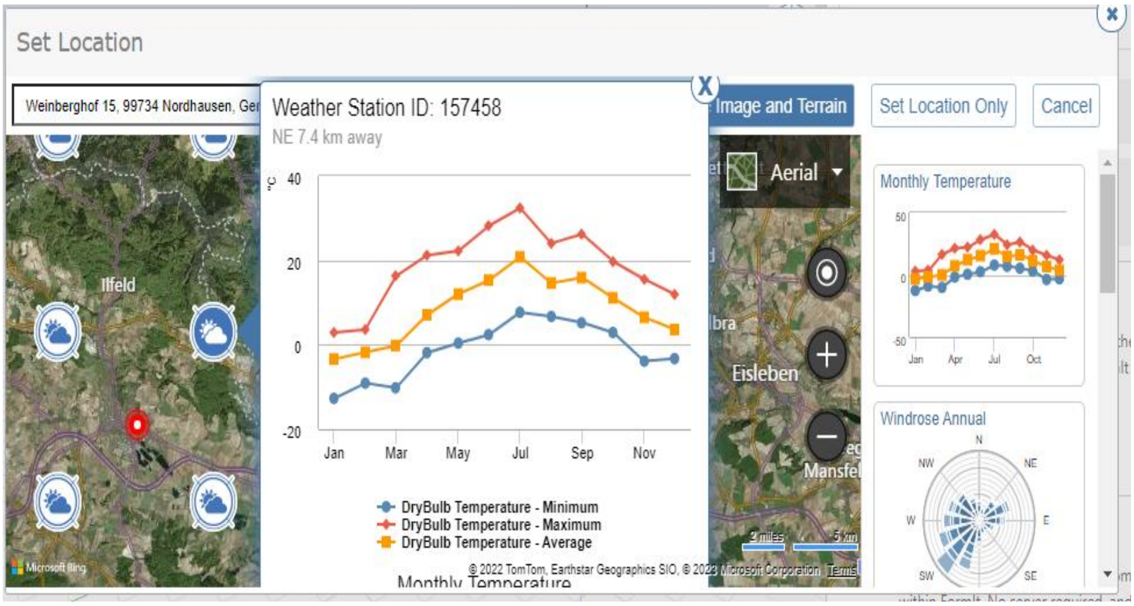

Figure 33 Temperature Over a year

The weather station is located 7.4 kilometers to the northeast of Building 19-20 [48] .

2. Windrose Weather Station 1

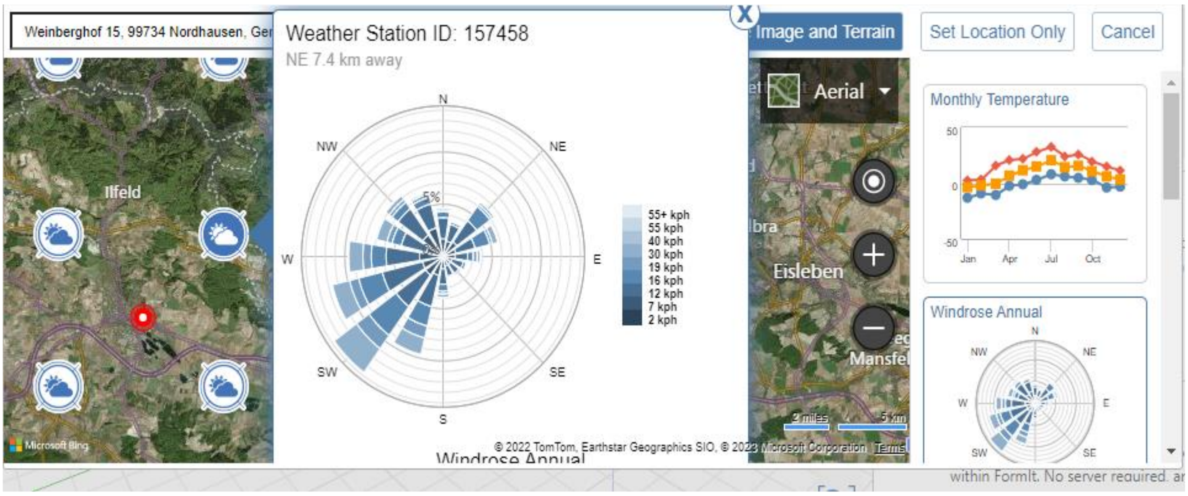

Figure 34 The weather station is 7.4 Km..[48]

1. Windrose Weather Station 2

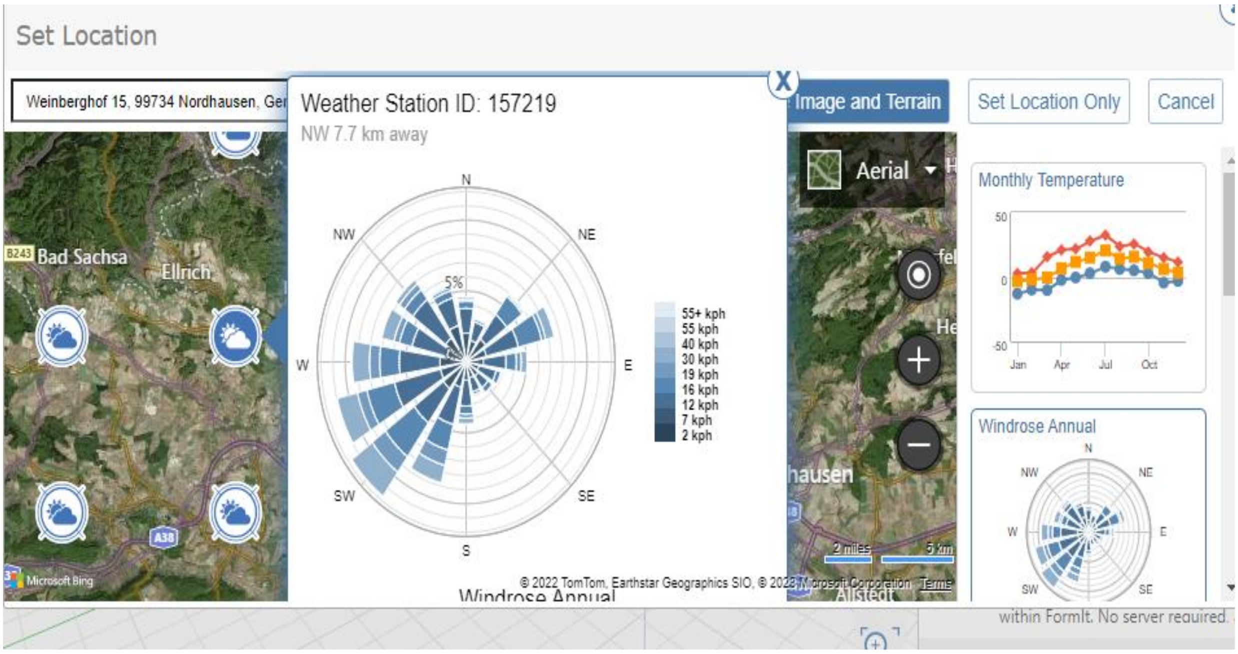

Figure 35 The Weather Station is 7.7 Km..[48]

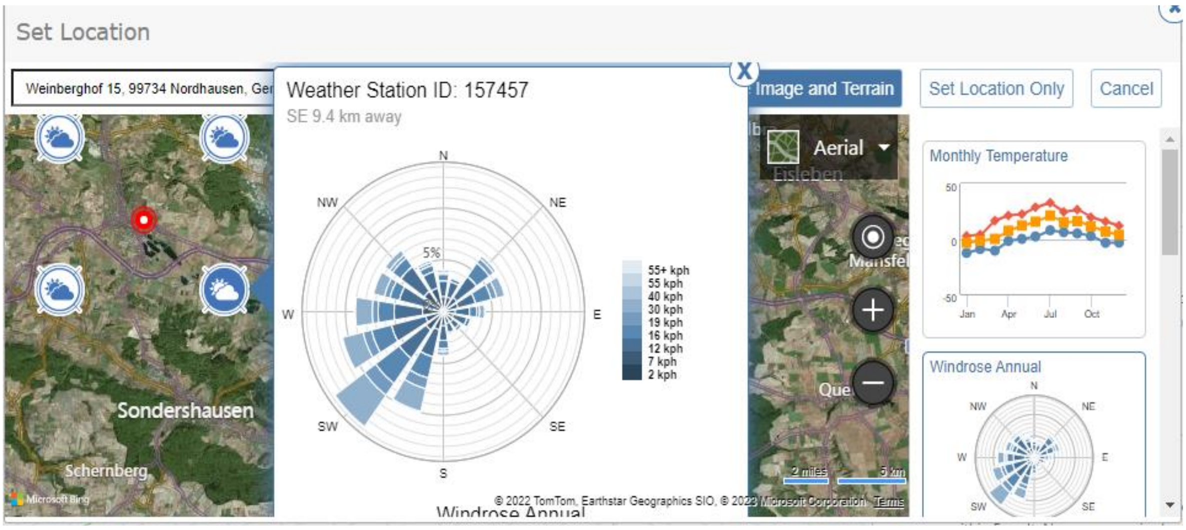

Figure 36 The Weather Station is 9.4 Km..[48].

2. Windrose Weather Station 4

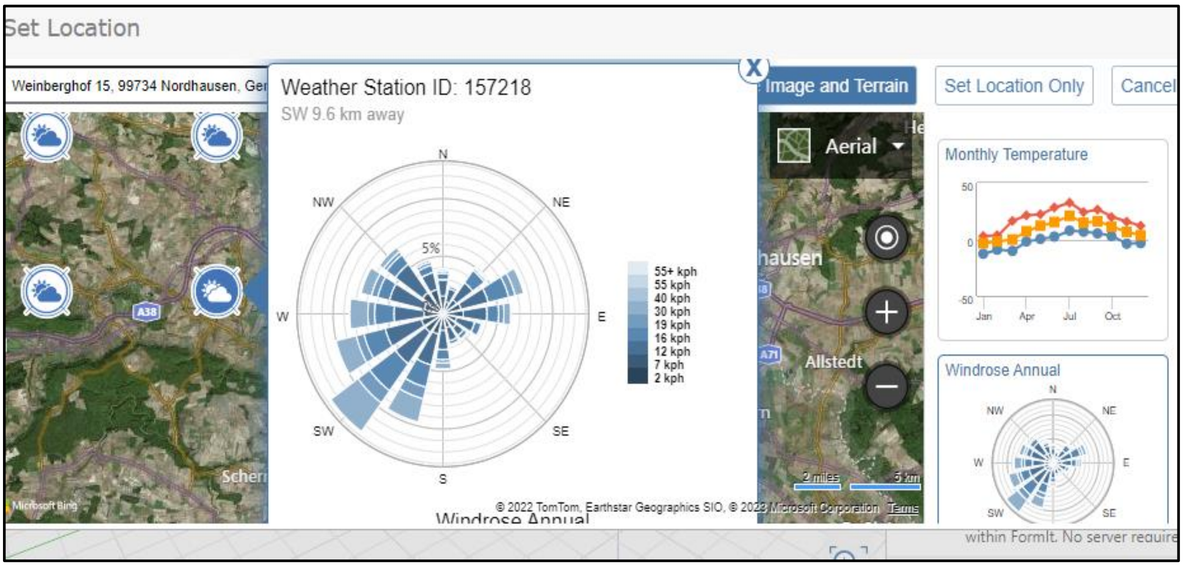

Figure 37 The Weather Station is 9.6 Km..[48]

- Wind Prospecting by Python Tool.

There is new technology that has arrived in the renewable energy system in wind power generation. This new technology is Aeromine Technology's wind rooftop technology. This new wind rooftops requires a flat roof of the building and wind from a single direction throughout the year to produce wind power, and our university buildings 19 is ideally located. Furthermore, to determine the wind potential of a specific location through prospecting and feasibility study.

There is a Requirement of data for the specific location for prospecting and feasibility of wind potential, and this data should be available. Regional or global data must be queried, summarized, and presented in an appropriate format to decision-makers. Data for the location is downloaded from a Nasa server in the form of a CSV file [47]. where location is Building no 19, Hochschule Nordhausen, Germany.

Python Tool is used in this case to read CSV file for building 19 location and present them in an appropriate format using various charts for determining wind potential, so that I can determine whether or not this building can be installed as a wind rooftop in both locations in Hochschule Nordhausen, Germany.
Requirements for Aeromine model to work:

(1) minimum wind speed must be greater than 2.5 m/s.
we can make sure that this location will work for our model or not right away by checking mean wind speed. By python Calculation, wind speed more than 2.5 m/s for the location at building 19 have 6006 records.

(2) Throughout the year anyone's direction should be more dominant than others so that we can install an Aeromine model in facing of that direction.
At Building 19,20 Location one dominant direction which Southwest and also windspeed more than 2.5 m/s for the location in Germany both of these conditions have 3140 records together. which is enough to determine the dominant direction. Facing of the Aeromine model must be in the Southwest direction.
Whereas other directions which have both condition fulfilled have less records

(3) Flat Roof Area.
As we know that Building 19 and 20 both have a flat roof area which is approximately 800 m² and 500 m² respectively.

3.8 Wind Roof top Technology by Aeromine Technologies

The innovation has been developed by a US start-up called Aeromine Technologies. Aeromine technologies with a revolutionary new roof-mounted design that has no visible moving parts, produces no noise, and can be used in conjunction with solar panels on the same roof to provide a far more consistent and continuous flow of electrical power to the building below. That is One of the major advantages that the Aeromine design has over pretty much all the other micro wind power generation systems that have come before [49].

Figure 38 Aeromine Unit [50]

- Components of Aeromine Unit:

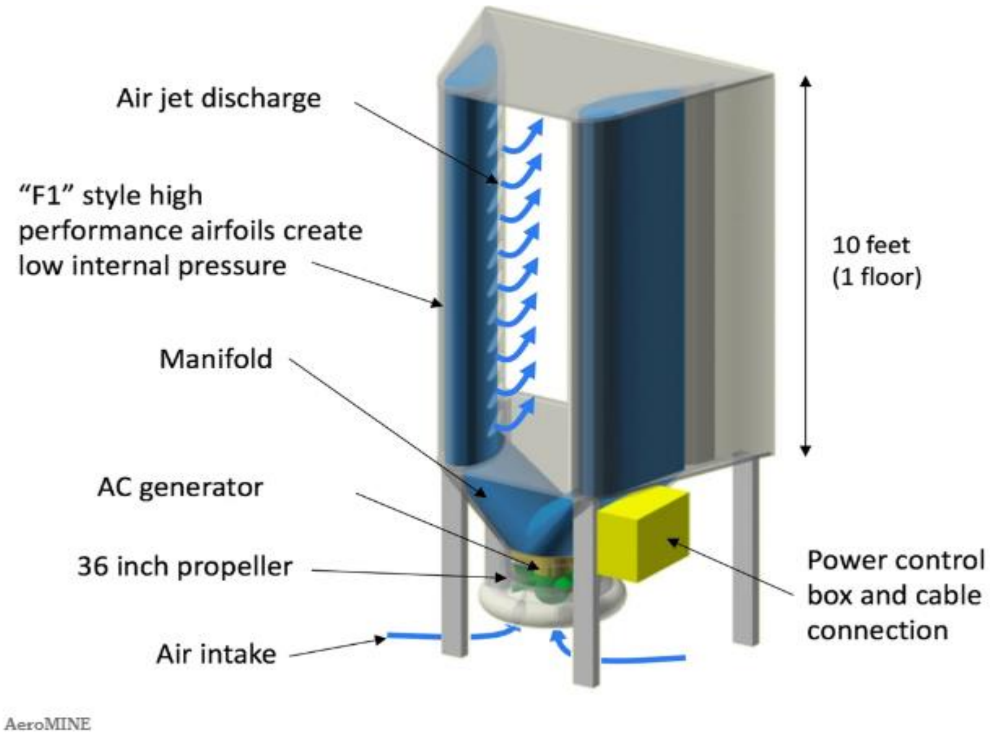

Figure 39 Components of Aeromine Unit [51]

Aeromine unit is made up of static Formula 1 race car aerofoils (hollow static aerofoils) that are manifolded, 36-inch propeller coupled to ac generator, which is connected to a power connection box via connection cables. The propeller is mounted inside the intake casing so that it makes no noise. The entire unit is designed in such a way that no visible parts to move, making it virtually silent .

- **Working principle of AeroMINE Unit:**

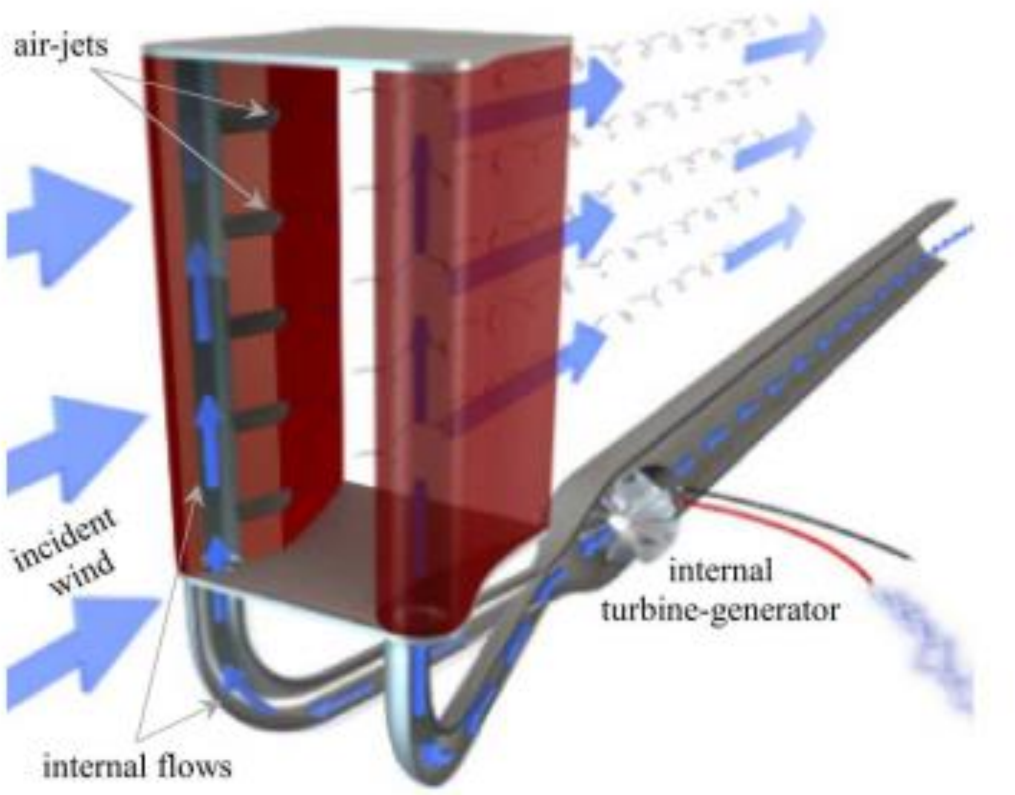

Figure 40 Working of AeroMINE unit[52]

schematic showing the operation of a single AeroMINE pair including semi-transparent/cutaway foilsand internal air flow. (Rendering by Vicente Garcia) [52].

The design's genius is based on two main principles: Bernoulli's effect and the Venturi effect.

The first is the shape of the top section's static airfoils. They are similar to components found on Formula One racing cars, which optimize wind flow and aerodynamic interactions across the vehicle to provide more downforce with the track while moving as quickly as possible. This downforce helps to stabilize vehicles and maintain speed as they turn corners. Bernoulli's Effect refers to the different rates at which gases and liquids flow around an object. A slower-moving fluid (such as air) will accumulate more pressure than a faster-moving fluid, causing objects to be drawn toward the faster-moving fluid.

The second effect is the Venturi effect, which occurs when a fluid is forced to flow through a constricted section of a pipe, increasing flow speed while decreasing fluid pressure. Fluids will always try to equalize the overall system by moving from a high to a low-pressure region.

The aerofoils on race cars, as well as the "Formula 1" style aerofoils that power the company's turbine, are stationary. There are no exposed moving parts when viewed from the outside. Instead, two vertically mounted, hollow foils with a space between them stand opposite each other. This creates a low-pressure zone, and wind is drawn through perforations in the wings as it flows through the space. A short pipe then transports the captured wind to a fully enclosed ground-level turbine. The structure of an Aeromine addresses several of the defects that afflict conventional turbines. Because the turbine-generator is housed inside, it is both safe from extreme weather and inaccessible to humans and animals, removing a major safety concern.

Limitations:

1. Because the System uses static airfoils, Aeromine only works in one direction. As a result, future development by the company for the Yaw mechanism for changing direction is still ongoing.

2. It requires a flat roof and a distance of 4 to 5 meters between two Aeromine units.

3. It can also operate in winds as low as 5 mph (8 kph). As a result, 8 km/h is required for the turbine to function.

Requirements of AeroMINE Units:

Table 16 Requirements of AeroMINE

Parameters	Requirement of AeroMINE	Building 19 & 20 Fulfilling the requirement.
Roof area	Need Flat Roof Area	Yes
Wind Speed	Need at least 2.23 m/s (8 Km/h)	Calculated Wind Speed 3.63 m/s by python
Wind Direction	Wind must be dominant at one direction	Wind is dominant in south West direction No or less obstacles in south West direction Elevated land is better for wind speed.

According to the table above, buildings 19 and 20 meet the requirements for AeroMINE units, so we can conclude that AeroMINE units can be installed in those structures.

Potential of one Aeromine Unit & Comparison with PV

Table 17 Potential Comparison

Parameters	PV	AeroMINE
Rated Power	5 kW system	5 kW
Annual Energy Production	4.2 MWh/ a for 16 panels [56]	14.5 MWh / a
Current Cost	2376 € / kW [54]	2376 € /kW (Which will be lower than solar after it goes in mass production)
Space acquired		10 % Space of Equivalent rated power of Solar

Comparison:

The Company claims it can Produce 50% more Power equivalent to 16 Solar panels at nearly same price .

The company claims that its "motionless" turbine can generate up to 50% more energy than solar panels while taking up only 10% of the space [49].

Advantages:

The Aeromine, according to the company, is silent and requires less maintenance due to its lack of exposed moving parts.

The company claims it can generate 50% more power than 16 solar panels combined if used in conjunction with solar power, which can provide higher energy yields [51].

According to the company, its "motionless" turbine can generate up to 50% more energy than solar panels while occupying only 10% of the space. When compared to other wind turbines, its ease of transport contributes to a lower carbon footprint.

- Geothermal Energy Potential

The ongoing conflict between Russia and Ukraine has significantly disrupted the natural gas supply to Europe, and as a result, Germany is coping with an energy crisis as a result of bans the EU has placed on Russian gas exports. So, Determining and assessing the potential for geothermal energy as a solution for heating and DHW (domestic hot water) needs of university buildings in an energy crisis situation across the country.

3.8.1 Rules and Regulations for Geothermal Energy and its Potential with potential sites

A. Geothermal Potential of Main Sports Ground ((Only heating) & (Heating and DHW Heating)).

- Hydrogeological and water management location survey for the use of geothermal probes

For the selected property in Nordhausen with the UTM coordinates 625744.0, 5706501.0 the following initial assessment results regarding the hydrogeological and water management framework conditions [53]:

- Hydrogeology

When planning a geothermal probe system, knowledge of the (hydro-)geological underground conditions is important. This allows the risk potential of the boreholes to be assessed for the groundwater. It also enables the companies commissioned with the planning to make an estimate of the drilling methods to be used as well as a time and financial calculation.

According to the documents available in the Thuringian State Office for the Environment, Mining and Nature Conservation (TLUBN), the top 100 m of the above-mentioned property is a hydrogeological unfavorable area I. See the TLVwA working aid "Surface geothermal energy". An individual assessment by the geological authority is recommended. If more detailed information on the rock sequence or groundwater level is required for planning, the Geological Service of the TLUBN offers a site-specific statement for a fee.

- Water Protection Area Law

According to Section 49 of the Water Resources Act (WHG) i. V. m. § 41 Thuringian Water Act (ThürWG) to report to the responsible lower water authority so that the protection of the groundwater can be reconciled with the use of geothermal energy.

According to the documents available in the TLUBN, it is a water management unfavorable area I. See the above work aid. An individual assessment by the geological authority is recommended. The site is within a Zone III water protection area. Geothermal systems have a high-risk potential if they tap the groundwater storey used for water extraction and/or are sunk within hydrogeological unfavorable areas.

The competent approval authority for the installation and operation of geothermal probes is the Lower Water Authority of the district of Nordhausen. The address of the Lower Water Authority is Nordhausen District Office, Lower Water Authority, Behringstraße 3, 99734 Nordhausen.

Boreholes that are to be deeper than 100 m are additionally included Thuringian State Office for the Environment, Mining and Nature Conservation (TLUBN); Department of Geology, Mining, Unit 84, Puschkinplatz 7 in 07545 Gera.

Geological investigations - excavations (boreholes, larger construction pits, measuring points) must be reported to the Thuringian State Office for the Environment, Mining and Nature Conservation (TLUBN) no later than two weeks before the start of construction without being asked, in accordance with Section 8 of the Geology Data Act (GeolDG). The e-mail address poststelle@tlubn.thueringen.de is available for transmission to disposal. The relevant forms and leaflets can be found at TLUBN [53]. more data available for deep drilling at this website in References [54].

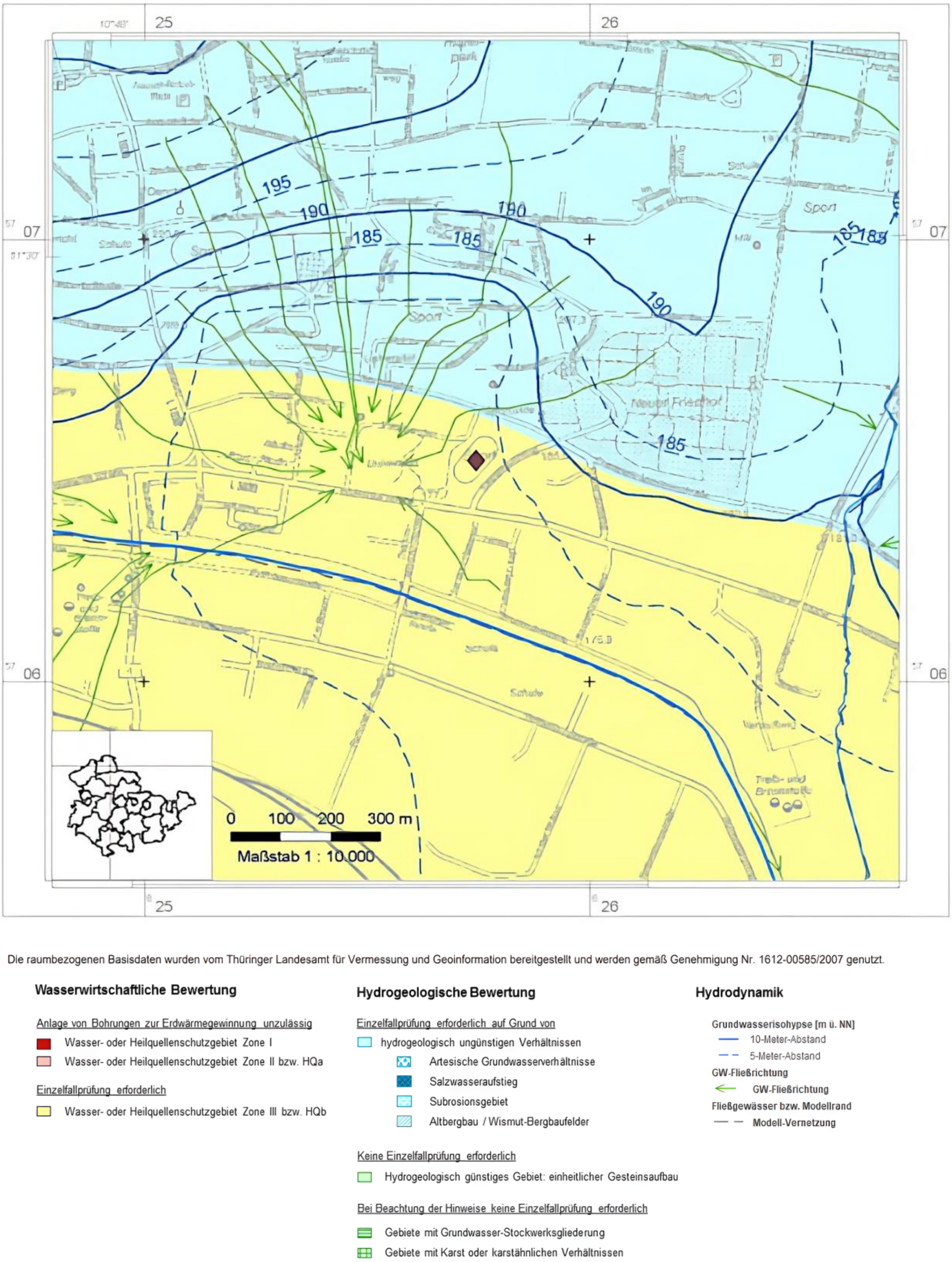

Figure 41 Geothermal Potential for main Sport Ground[53]

Information on the geothermal potential at the selected location (main Sports Ground (only heating) & (Heating and DHW Heating))

The best possible knowledge of the thermal properties of the subsoil is a basic requirement for planning a geothermal system. For the correct design of geothermal-based heating systems, the specific extraction capacity [W/m] is used as a relevant parameter. The specific extraction capacity is a function of the thermal conductivity [λ] of the subsoil (a measure of heat transport capacity) and varies depending on the subsoil properties and water content.

- **Map Display**

For the selected property, the following geothermal assessment results with regard to the specific thermal conductivity λ

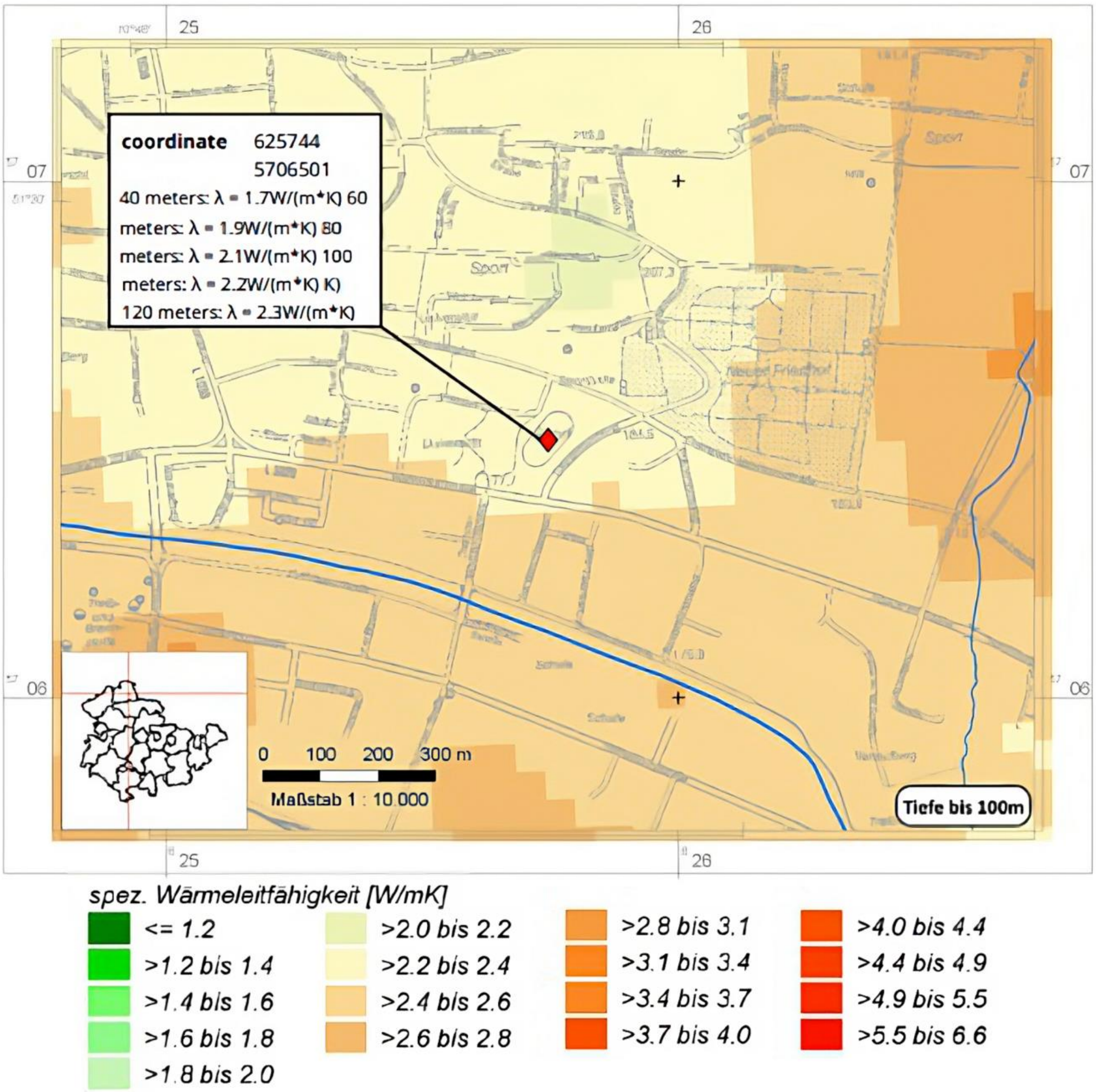

Figure 42 Specific thermal conductivity for main sports ground location[53]

The following specific thermal conductivities were calculated for the property with different depths:

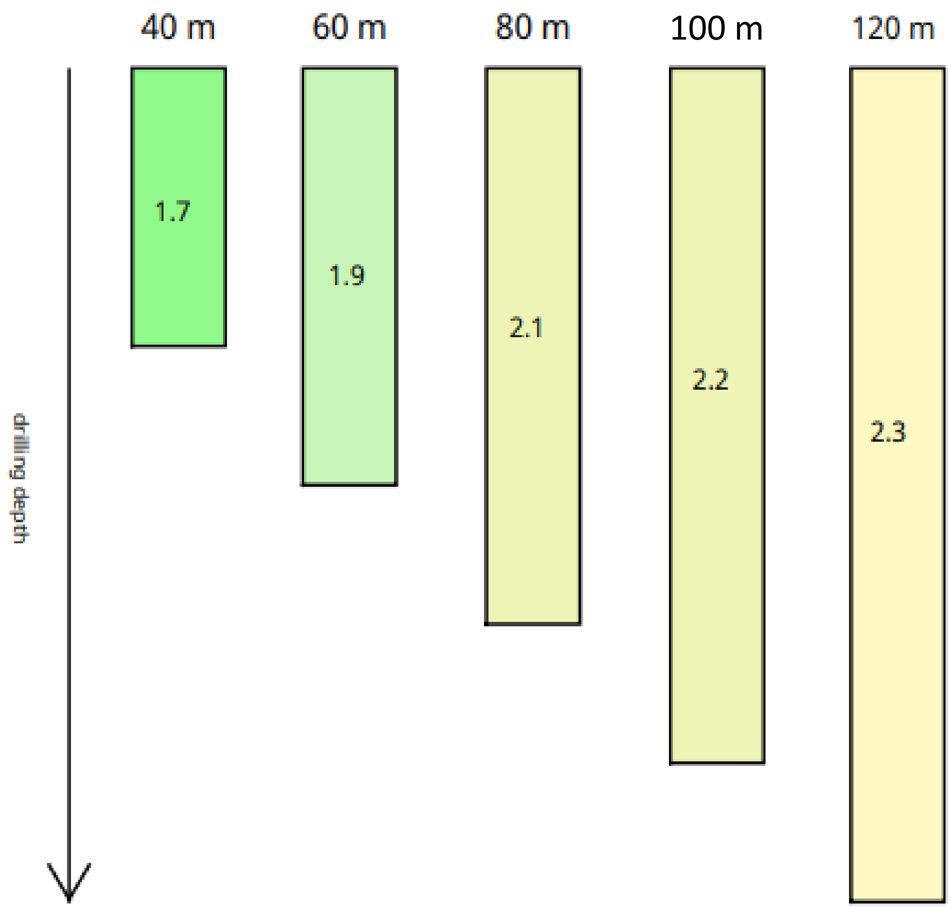

Figure 43 Specific thermal conductivity for main Sport ground[53]

Estimation of the specific extraction capacity (applies only to boundary conditions, among others):

For smaller systems with a heating capacity of up to 30 kW, the table below shows the extraction capacity in W/m and the geothermal yield [kWh/(ma)] for the selected configuration. The procedure and general conditions under which this table may be used is described in VDI guideline 4640 sheets 2 in section 7.1.2 [55].

Table 18 Energy Potential for Main Sports Ground (only Heating)

Chosen Configuration: Plant operation: only Heating (Sports ground)			
Annual Full load hours:		2400	
Outlet Temperature of heat Pump at peak load T_{wpexit}		Twp >= - 3	
Number of Holes:		3	
Depth[m]	Medium thermal Conductivity Capability [W/m.K]	Potential Withdrawal Service [W/m]	Geothermal Fertility [kWh/m.a]
0 to 40 m	1.7	23.8	57.1
0 to 60 m	1.9	25.7	61.7
0 to 80 m	2.1	27.5	66
0 to 100 m	2.2	28.3	67.9
0 to 120m	2.3	29.2	70.1

Table 19 Energy Potential for Main Sports Ground (Heating and DHW heating)

Chosen Configuration: Plant operation: Heating and DHW Heating (Sports ground)			
Annual Full load hours:		2400	
Outlet Temperature of heat Pump at peak load T_{wpexit}		Twp >= - 3	
Number of Holes:		5	
Depth[m]	Medium thermal Conductivity Capability [W/m.K]	Potential Withdrawal Service [W/m]	Geothermal Fertility [kWh/m.a]
0 to 40 m	1.7	21.9	52.6
0 to 60 m	1.9	23.7	56.9
0 to 80 m	2.1	25.3	60.7
0 to 100 m	2.2	26.1	62.6
0 to 120m	2.3	26.9	64.6

B. Location: Open Space area near the Lake (Only Heating)

- Hydrogeological and water management location survey for the use of geothermal probes

  For the selected property in Nordhausen (Nordhausen)with the UTM coordinates 625660.0, 5706515.0 the following initial assessment results with regard to the hydrogeological and water management framework conditions which are same as Sports Ground.

- Hydrogeology

  According to the documents available in the Thuringian State Office for the Environment, Mining and Nature Conservation (TLUBN), the top 100 m of the above-mentioned property is a hydrogeological unfavorable area I. See the TLVwA working aid "Surface geothermal energy". An individual assessment by the geological authority is recommended. If more detailed information on the rock sequence or groundwater level is required for planning, the Geological Service of the TLUBN offers a site-specific statement for a fee.

- Water Protection Area Law

  According to the documents available in the TLUBN, it is a water management unfavorable area I. See the above work aid. An individual assessment by the geological authority is recommended. The site is within a Zone III water protection area. Geothermal systems have a high-risk potential if they tap the groundwater storey used for water extraction and/or are sunk within hydrogeological unfavorable areas.

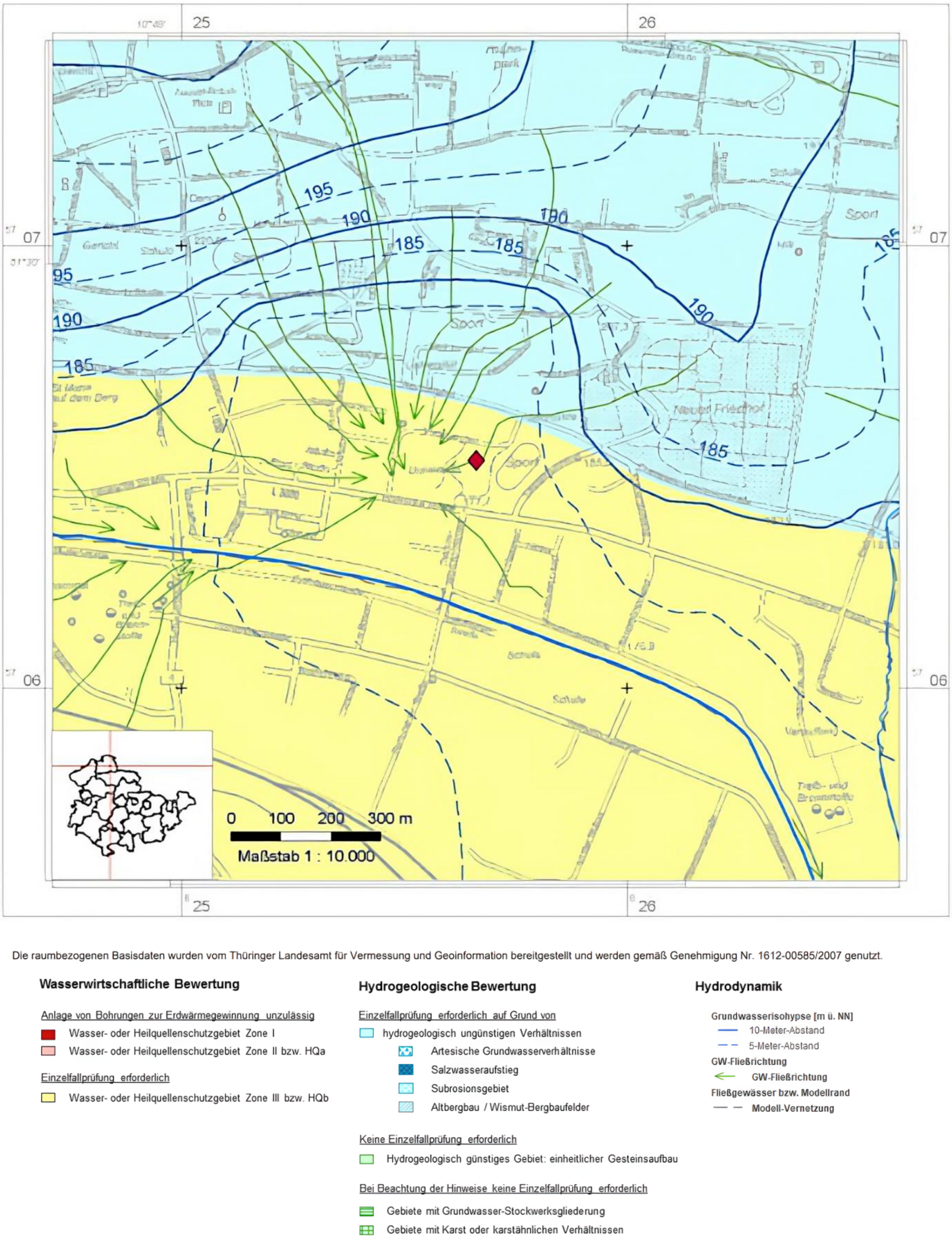

Figure 44 Geothermal Potential for open space near Lake[53]

Information on the geothermal potential at the selected location (Lake only heating)

The best possible knowledge of the thermal properties of the subsoil is a basic requirement for planning a geothermal system. For the correct design of geothermal-based heating systems, the specific extraction capacity [W/m] is used as a relevant parameter. The specific extraction capacity is a function of the thermal conductivity [λ] of the subsoil (a measure of heat transport capacity) and varies depending on the subsoil properties and water content.

- **Map Display**

For the selected property, the following geothermal assessment results with regard to the specific thermal conductivity λ:

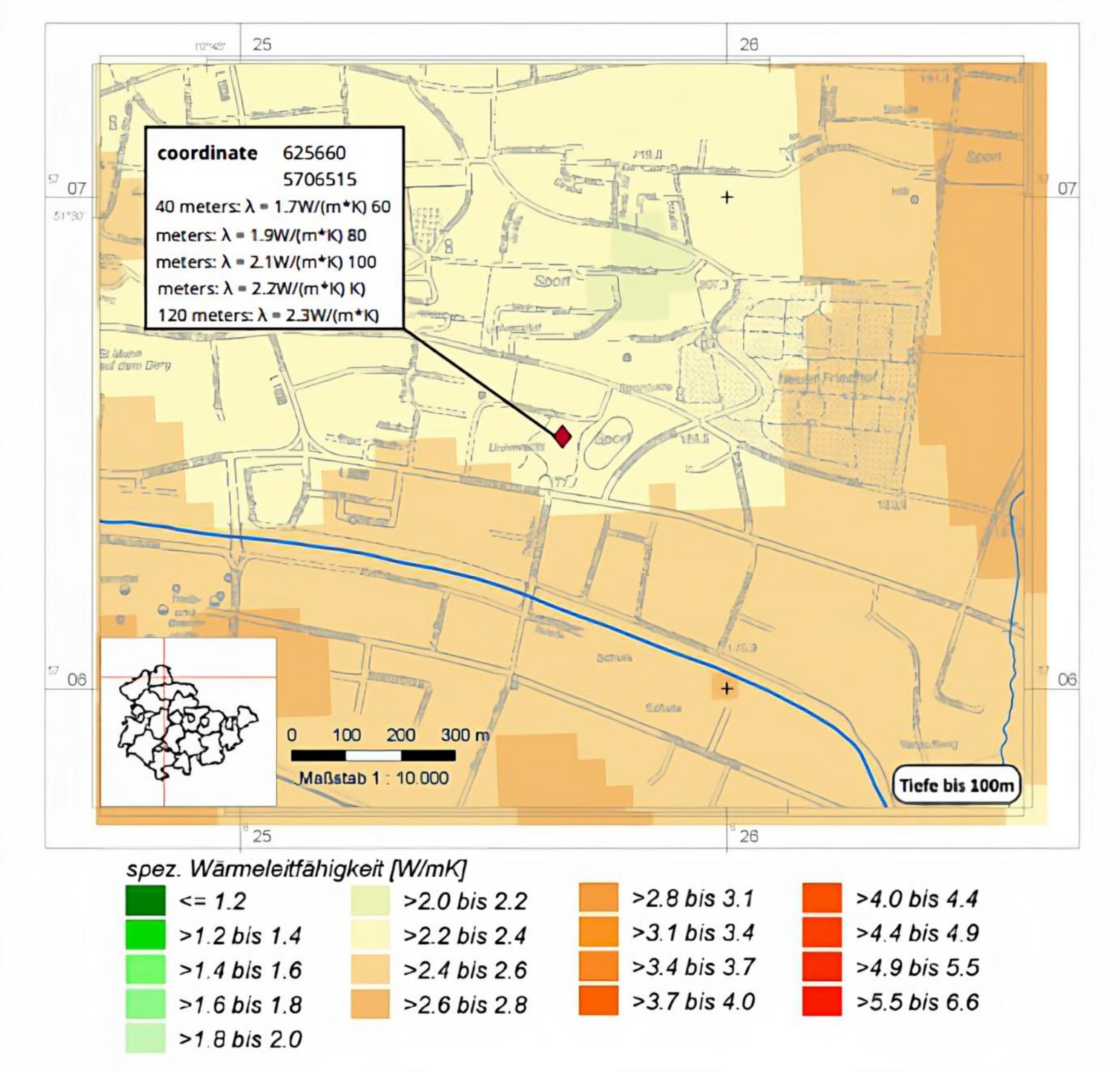

Figure 45 Specific thermal conductivity space area near Lake location

The following specific thermal conductivities were calculated for the property with different depths:

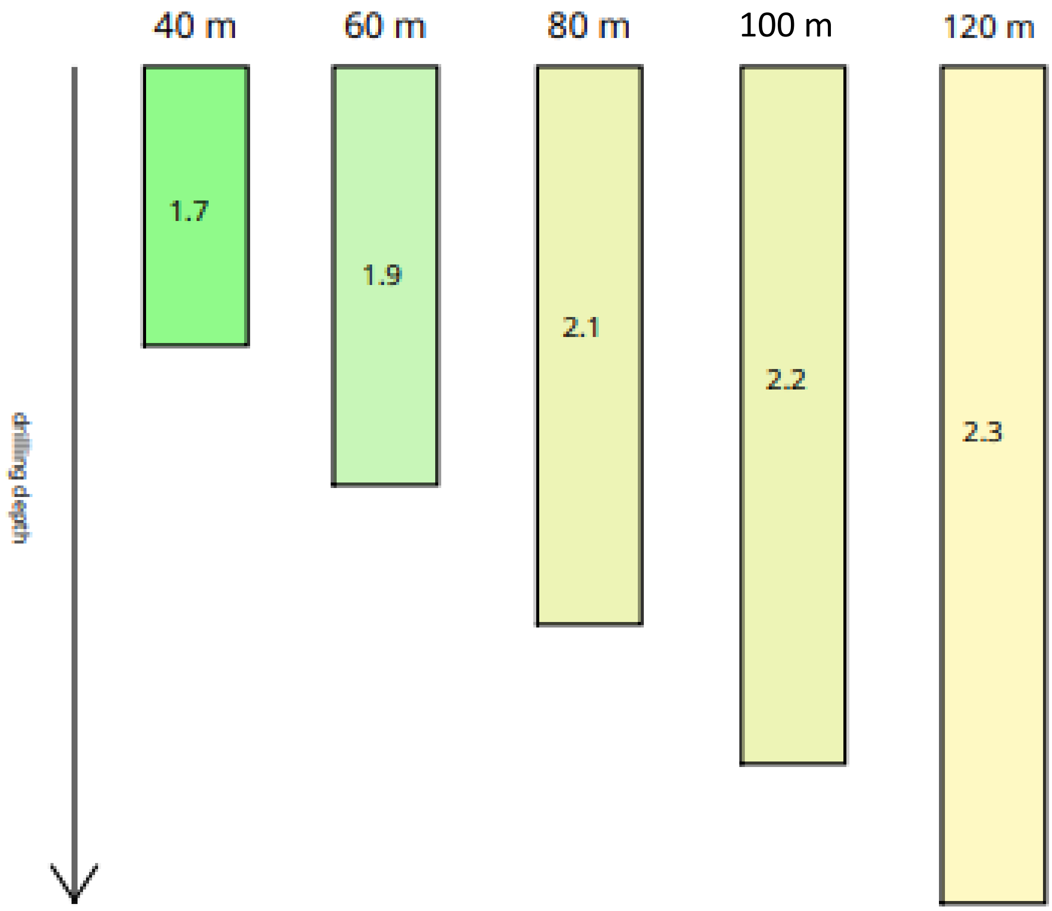

Figure 46 Specific thermal conductivity open space area near lake

Estimation of the specific extraction capacity (applies only to boundary conditions, among others**:**

For smaller systems with a heating capacity of up to 30 kW, the table below shows the extraction capacity in W/m and the geothermal yield [kWh/(ma)] for the selected configuration. The procedure and general conditions under which this table may be used is described in VDI guideline 4640 sheets 2 in section 7.1.2 (June 2019).

Table 20 Energy Potential for Open Space near Lake

Chosen Configuration: Plant operation: only Heating (Open Space area near Lake)			
Annual Full load hours:		1800	
Outlet Temperature of heat Pump at peak load T_{wpexit}		Twp >= - 3	
Number of Holes:		2	
Depth[m]	Medium thermal Conductivity Capability [W/m.K]	Potential Withdrawal Service [W/m]	Geothermal Fertility [kWh/m.a]
0 to 40 m	1.7	30.5	54.9
0 to 60 m	1.9	32.6	58.7
0 to 80 m	2.1	34.6	62.3
0 to 100 m	2.2	35.5	63.9
0 to 120m	2.3	36.4	65.5

C. Location : Sport Ground Behind Studentenwerk (Heating and DHW Heating)

- Hydrogeological and water management location survey for the use of geothermal probes

For the selected property in Nordhausen (Nordhausen)with the UTM coordinates 625623.0, 5706792.0 the following initial assessment results with regard to the hydrogeological and water management framework conditions which are different than previous location.

- Hydrogeology

According to the documents available in the Thuringian State Office for the Environment, Mining and Nature Conservation (TLUBN), the top 100 m of the above-mentioned property is a hydrogeological unfavorable area I. See the TLVwA working aid "Surface geothermal energy". An individual assessment by the geological authority is recommended. If more detailed information on the rock sequence or groundwater level is required for planning, the Geological Service of the TLUBN offers a site-specific statement for a fee.

- Water Protection Area Law

According to the documents available in the TLUBN, it is a favorable water management area I. See the above work aid. The site is outside of water or mineral spring protection areas.

The competent approval authority for the installation and operation of geothermal probes is the Lower Water Authority of the district of Nordhausen. The address of the Lower Water Authority is: Nordhausen District Office, Lower Water Authority, Behringstraße 3, 99734 Nordhausen.

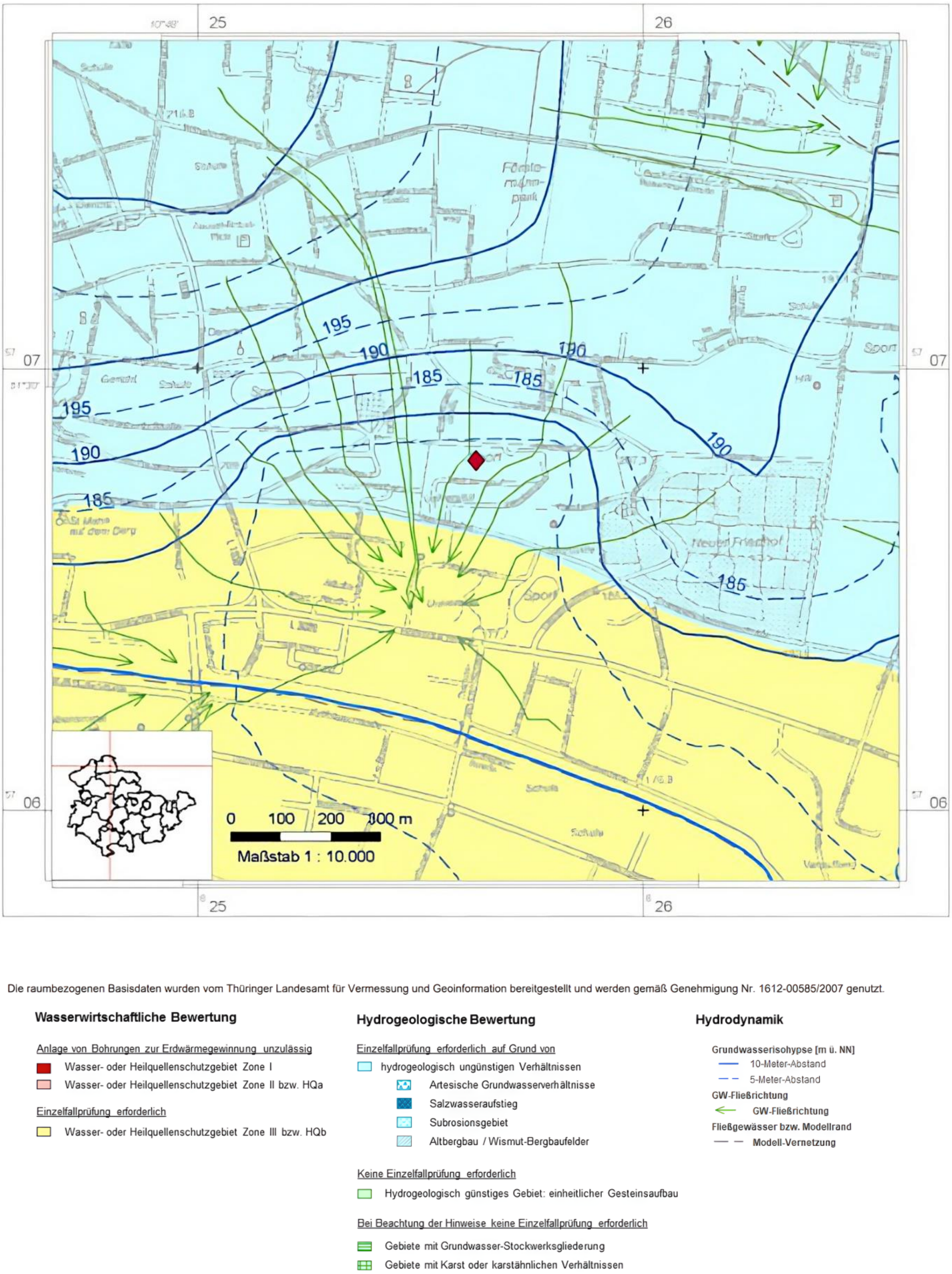

Figure 47 Geothermal Potential Ground behind Studentenwerk Building[53]

Information on the geothermal potential at the selected location (Lake only heating)

The best possible knowledge of the thermal properties of the subsoil is a basic requirement for planning a geothermal system. For the correct design of geothermal-based heating systems, the specific extraction capacity [W/m] is used as a relevant parameter. The specific extraction capacity is a function of the thermal conductivity [λ] of the subsoil (a measure of heat transport capacity) and varies depending on the subsoil properties and water content.

- **Map Display**

For the selected property, the following geothermal assessment results with regard to the specific thermal conductivity λ:

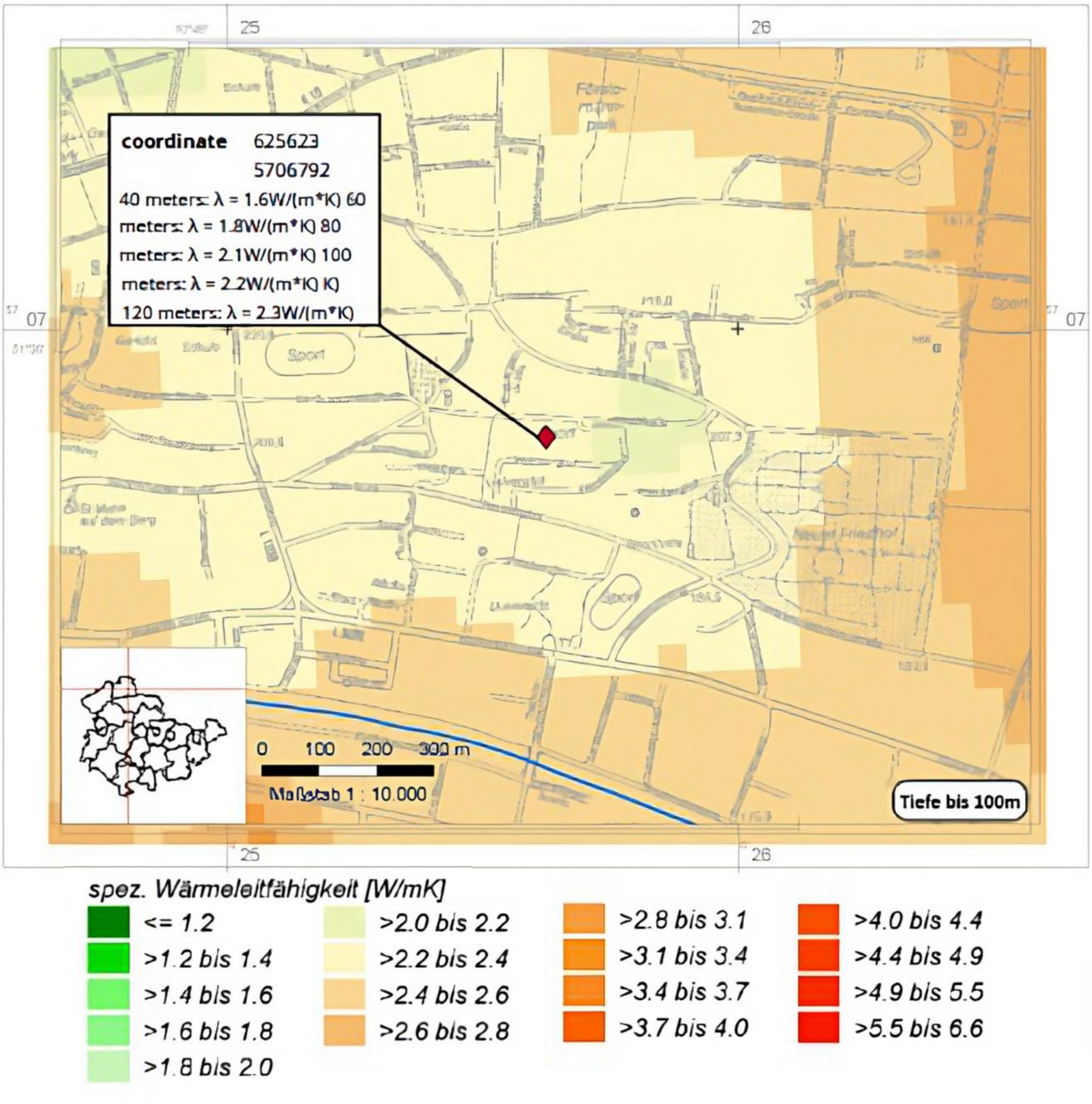

Figure 48 Specific thermal conductivity ground behind Studentenwerk location[53]

The following specific thermal conductivities were calculated for the property with different depths:

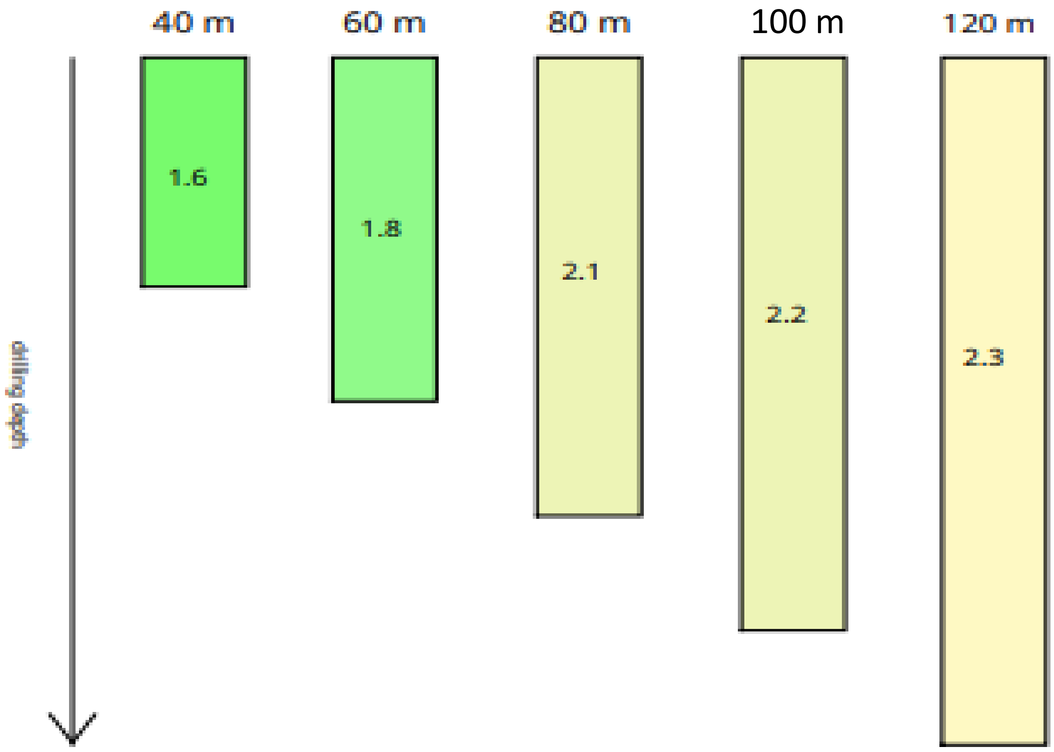

Figure 49 Specific Thermal conductivity ground behind Studentenwerk Building[53]

Estimation of the specific extraction capacity (applies only to boundary conditions, among others):

For smaller systems with a heating capacity of up to 30 kW, the table below shows the extraction capacity in W/m and the geothermal yield [kWh/(ma)] for the selected configuration.

Table 21 Energy Potential for sports ground behind Studentenwerk building

Chosen Configuration: Plant operation: Heating & DHW Heating (Sports Ground behind Studentenwerk)			
Annual Full load hours:		2400	
Outlet Temperature of heat Pump at peak load T_{wpexit}		Twp >= - 3	
Number of Holes:		4	
Depth[m]	Medium thermal Conductivity Capability [W/m.K]	Potential Withdrawal Service [W/m]	Geothermal Fertility [kWh/m.a]
0 to 40 m	1.6	21.8	52.3
0 to 60 m	1.8	23.7	56.9
0 to 80 m	2.1	26.4	63.4
0 to 100 m	2.2	27.2	65.3
0 to 120m	2.3	28	67.2

3.9 Economic Analysis Methodology

An economic analysis of the Renewable Energy Project in Hochschule Nordhausen Campus. PV modules are selected as the renewable energy source which could act as an alternative of the energy from the electrical grid.

Economic analysis involves assessing or examining topics or issues from an economist's perspective. Economic analysis is the study of economic systems. It may also be a study of a production process or an industry. The analysis aims to determine how effectively the economy or something within it is operating.

Design, construction, and implementation of engineering systems are ultimately decided by economic decisions [64]. The economics of energy systems includes initial cost of delivering components that function in the system (turbines, high-voltage transmission lines and so forth), ongoing costs associated with fuel, maintenance, wages, and other costs, and the price that can be obtained in the market for a kWh of electricity [61]. However, many different energy technologies exist for generating electricity: coal-fired steam power plants, gas turbine combined-cycle power plants, fuel cells, hydropower power plants, wind power, solar, and many others. When comparing these different technologies for an energy system, a method is needed that incorporates the role of both initial capital costs and ongoing operating costs [61-63].

Several types of economic analysis are executed for different desired outcomes. The main types of analysis are:

- Cost - Benefit Analysis
- Cost - Effectiveness Analysis
- Cost - Utility Analysis

One of the tools commonly used and accepted by industry is known as Levelized Cost of Energy (LCOE) [61-63]. LCOE is a useful metric used to compare an owner's life-cycle cost by converting all costs into a single cost of electricity rate, expressed in euros per kilowatt-hour of electricity [62].

The levelized cost per unit of energy output provides a way to combine all cost factors into a cost-per-unit measure that is comparable between technologies. It can be defined as [61]

$$LCOE = \frac{total\ annual\ cost}{annual\ system\ output}$$

where total annual cost = annualised capital cost + operating cost + return on investment (ROI).

Table 22 Total LCOE for various technologies

Plant type	Capacity Factor (%)	Fixed O&M (%of CAPEX/year)	Variable O&M (euro/MWh)	Total system Levelized cost(euro/MWh)
Solar PV	9-14%	2%	0.00	220
Wind-onshore	23-36%	1%	0.02	59
Wind-offshore	34-49%	2%	0.39	84
Hydropower	22%	2%-3%	0.00	69
Coal power plants	80%	1.6%-2.4%	2.4-4.16	2018
Biomass	80%	4%	3.96	30-42

1. Macroeconomic context: With the introduction of new courses and programmes, Hochschule Nordhausen has a significant growth in the number of students and thus also increasing the revenue as well as the maintenance and several other costs.

2. Sector Context: Hochschule Nordhausen relies on Power grid stations for electricity and on natural gas for various heating applications. The energy is received and distributed across the campus for use in different purposes. Five buildings and a parking rooftop is selected for this analysis

3.10 Transportation Methodology

Transportation is one of the important part for the green campus. It has an impact on the campus environment including Air pollution (CO_2 Emission) and Energy consumption. The major sources of CO_2 emission are mainly depending on electricity usage, vehicular movement, and Waste disposal. Therefore, substantial investigation is required to cut down on the emission rate for the green campus of HSN and which are the possible solutions to reduce emission and generate more energy to utilize the parking places. That depends on the parking area, the movement of cars and buses every day, how frequent they come, the distance they travel, time it takes to reach university, travel with co-passenger or individually and come by car in every season (Summer and winter).

The HSN campus has 4 level of parking places with handicapped parking and EV charging stations. Moreover, we did survey about the average numbers of car park in the daily bases and the total carbon dioxide emitted by the cars in the tons at the HSN in one hour, this data and survey observed over two days at different times. And, we did survey of 25 students for real-time data. There are 3 buses come to HSN per hour and they travel around 20km every hour.

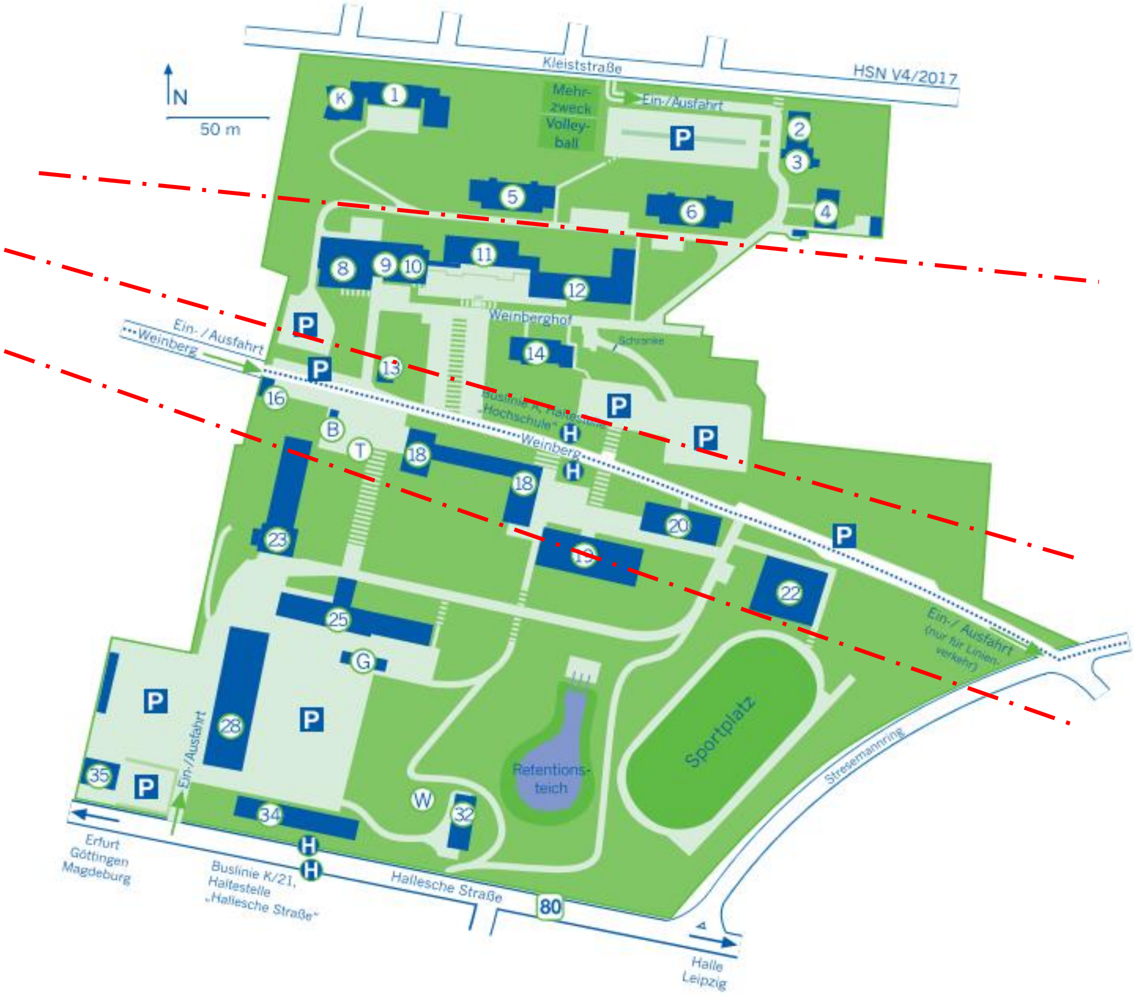

Figure 50 Campus Divided layout

There are several ways to reduce the CO_2 emission, that is providing Solar shaded parking, travel with co-student, use of maximum public transport and electric vehicle. The initial cost will be high for solar shaded parking but it will generate electricity that will use for free charging to students and staff and for others it will be for nominal price and the remaining electricity we can use for another purpose like street light. Another way is to reduce emission is that carpooling. People who are travel though the same route they can share expenses or use their car on alternate days. And another possible way is to maximum use of public transport and bicycle mostly in the summer.

The HSN campus is divided into 4 levels as shown in the above figure for the calculation of the average number of cars parked. Parking places are available for different buildings on each level of the campus plan and it is shown as legend P in the campus plan.

HSN campus has parking places for four levels and also handicapped parking places and EV charging stations which are shown in the below figures.

Figure 51 Level 1

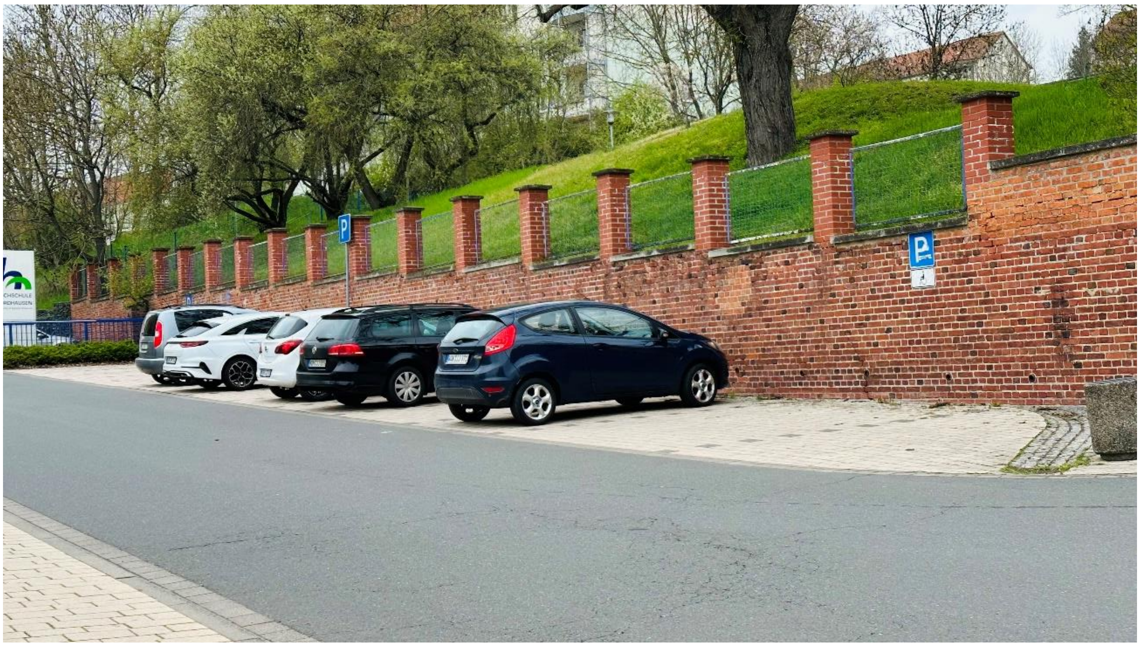

Figure 52 Level 2

Figure 53 Level 3

Figure 54 Level 4

Figure 55 EV charging station in Level 1

Figure 56 Physically handicapped parking at level 1

3.11 Sustainability Analysis Methodology

In the sustainability amassment analyzing the life cycle assessment (LCA) of the PV modules which are the central part of the solar PV system disregard the LCA of inverters and other components. In the LCA assessment, the product was described from the extraction and production phase to end of life phase.

The following flowchart shows an LCA of the PV modules.

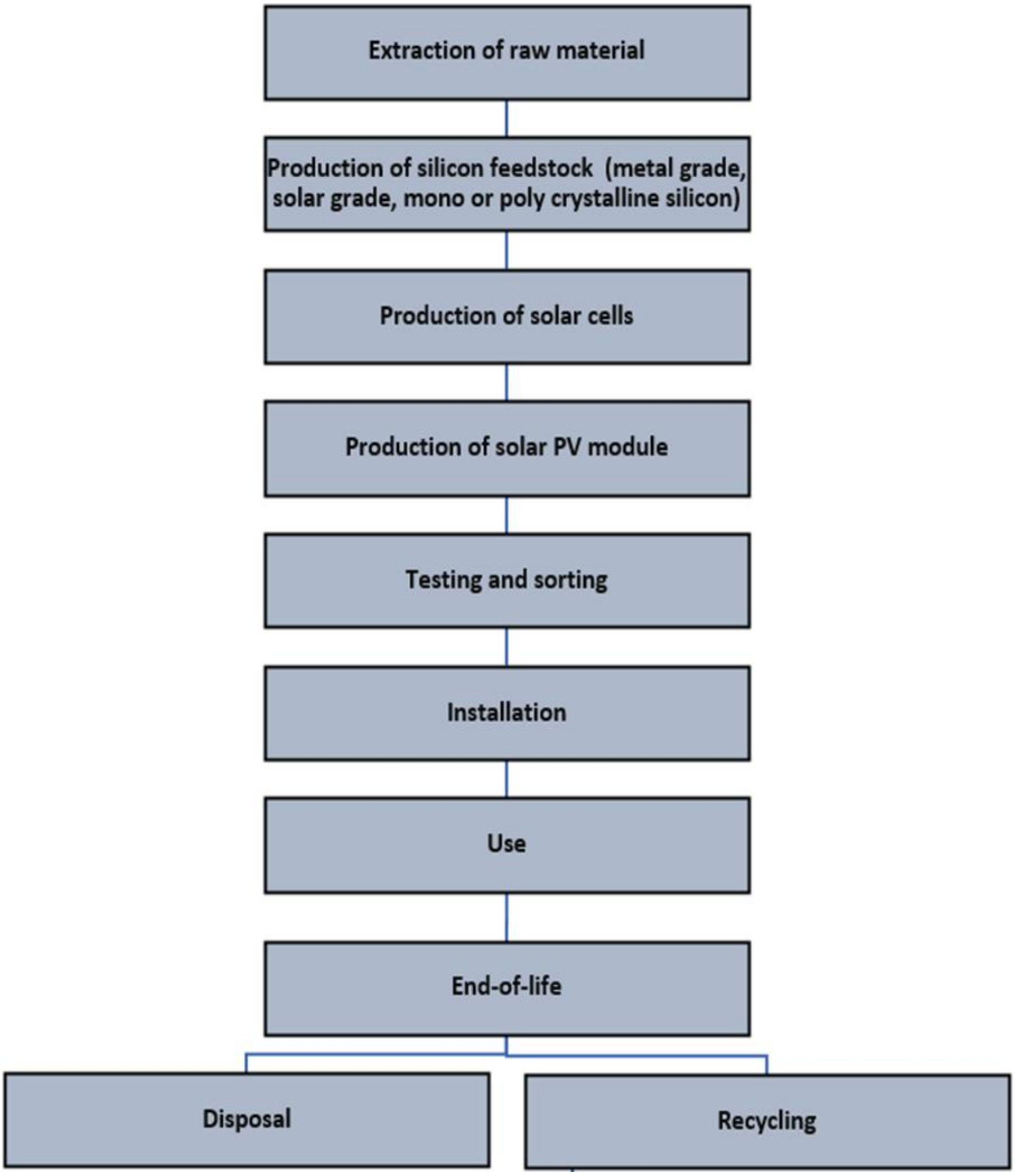

Figure 57 Flowchart of LCA of PV module [70]

4. Calculation and Results

4. Calculation and Results

4.1 Results from Data Acquisition

The aim of the data acquisition is to get the necessary data needed for the implementation of our project 'Green Campus'. The data collection involves physical measurement of 23 available buildings of which one of the buildings is still under construction, hence was not measured. Furthermore, other considered areas for renewable energy potential includes, parking slots which are suitable for the analysis of our project. What was majorly considered during the collection process was a focus on the entire campus which includes the student's residence and administrative buildings and available areas suitable for photovoltaic potentials, this including rooftop of buildings. In addition, the reference for formation of specific data includes the campus map from the university management, google map, and solar-rechner. The data collected will act as a source of information to develop the renewable energy potential towards achieving a green campus at the Hochschule Nordhausen.

Table 23 Area of residential buildings

Building	Total number of rooms	Total area (in m^2)
5 & 5a	58	595
6 & 6a	111	600
7	46	609
13	6	247
14 & 14a	37	340

- Helmestraβe

Table 24 Area of administration building

Building	Total number of rooms	Total area (in m^2)
International office (8), Karzer (9), Mensa (10)	71 (including a dining hall)	1217
Audimax (11)	3 rooms & 1 seminar	416
Studienkolleg (12)	33	841
13	6	247
President’s office (14)	35	365
16	3	70
18	75	1116
19	28	865
20	43	547
25	25	1022
28	20	1461
32	20	384
34	19	645
35	12	240

4.2 Results from Heat Energy Supply

4.2.1 Calculation for Heat Energy Supply

- Domestic Hot Water (DHW)

A Domestic Hot Water (DHW) System provides hot water to fixtures, where water may come into contact with humans. It is operated by delivering hot water via a centralized storage tank separate from the water used for steam or hydronic heating. DHW is operated similarly in commercial and residential systems. A central water body of hot water is heated to 60℃ to 70℃, and before delivering to taps it is cooled by a mixing valve to 45℃ to 55℃ to avoid scalding. DHW systems must be monitored and well-covered to avoid the proliferation of dangerous legionella bacteria.[1]

Here, we have calculated the heat demand required for DHW throughout the year. For that, we have considered the flow of 15 L/day for commercial buildings and 50 L/day for residential buildings. Weinberghof's are residential and buildings-n are commercial. The maximum heating temperature is 55℃ and the minimum is 10℃. We gathered data on the number of taps, showers, and sinks from all buildings to calculate the total mass flow of water.

$$Q = \dot{m} \times C_p \times \Delta T$$

where,

Q= Heat demand (MWh)

$\dot{m}$ = mass flow of water (Kg)

C_p-specific heat of water (4.2 KJ/Kg-K)

ΔT = Temperature difference.

For commercial buildings, after neglecting public holidays and semester breaks, we calculated 204 days; on the other hand, for residential days we considered a year of 365 days.

In the below tabular column, Q is the calculated heat demand generated for a year in MWh.

Table 25 Heat Demand of Various Buildings

Building Name	No. of Taps	Total mass (kg)	Q(KJ/day)	Q(MWh)/year
Building 34	11	165	31185	1,767
Building 28	9	135	25515	1,445
Building 18	20	300	56700	3,213
Building 19	14	210	39690	2,249
Building 8,9,10	12	180	34020	1,927
Building 11	4	60	11340	0,642
Building 12	5	75	14175	0,8032
Building 13	0	0	0	0
Building 16	1	15	2835	0,160
Building 20	4	60	11340	0,6426
Building 25	6	90	17010	0,9639
Building 32	10	150	28350	1,606
Building 35	8	120	22680	1,285
weinberghof - 5	64	3200	604800	61,32
weinberghof - 6	66	3300	623700	63,23
weinberghof-7	46	2300	434700	44,07
weinberghof-13	20	1000	189000	19,162
weinberghof - 14	28	1400	264600	26,827

- Space Heating:

Solar space heating is a natural application of solar thermal energy which uses incident solar radiation to warm up spaces within buildings. Passive Space Heating and Active Space Heating are the two types of space heating.[2] Passive solar space heating is accomplished by locating and crafting the home and landscape aspects in such a way in the energy from the sun that reaches the residence is maximized. For instance, windows facing the south will maximize the home's exposure to solar radiation. Solar collectors help to absorb solar radiation in active space heating. Mechanical equipment like pumps, fans, and air handling units are used in systems to accumulate, store, and disburse heat throughout the house. Whereas heat distribution occurs through convection, conduction, and radiation. Active solar heating systems are categorized as air systems and liquid systems based on fluid type.[3]

Earlier we have shown a calculation for total heat demand. The total heat demand is divided into Space heating and Domestic water heating. So, the below tabular column shows the heat demand for space heating. where total head demand and space heating is calculated in MWh and DHW in KWh.

Table 26 Space Heating

Building Name	Total Heat Demand (MWh)	Domestic Water Heating (KWh)	Space Heating (MWh)
Building 34	98.56	1767.15	96.79285
Building 28	149.21	1445.85	147.76415
Building 18	485.17	3213	481.957
Building 19	254.76	2249.1	252.5109
Building 8,9,10	540.71	1927.8	538.7822
Building 11	104.18	642.6	103.5374
Building 12	962.35	803.25	961.54675
Building 13	27.54	0	27.54
Building 16	15.55	160.65	15.38935
Building 20	500.28	642.6	499.6374

Building 25	467.84	963.9	466.8761
Building 32	87.74	1606.5	86.1335
Building 35	112.85	1285.2	111.5648
weinberghof 5	204.65	61320	143.33
weinberghof 6	271.72	63236.25	208.48375
weinberghof 7	117.36	44073.75	73.28625
weinberghof 13	122.27	19162.5	103.1075
weinberghof 14	136.43	26827.5	109.6025

4.2.2 Calculation and Result for Heat Load Profile

The purpose of this analysis is to evaluate the total heat consumption of 21 buildings at Hochschule Nordhausen. For providing the better understanding of the university, the university has been separated into North campus and South campus. The goal is to determine the amount of heat consumed for each building, as well as percentage share of heat consumption in north and south campuses. Additionally, this analysis will examine the utilization of heat consumption in the university, specially focusing on the amount of heat consumed used for Domestic water heating and Space heating. The methodology involved selecting 4 different categorized representative buildings (19, 28, 34, and Weinberghof 7) that includes both commercial and residential types. A Python code was used to calculate the total heat consumption of these four buildings. These four buildings served as a representative sample to determine the amount of heat consumed per square meter of area, which was then used as a basis to estimate the heat consumption of the remaining buildings.

The results of the analysis of four chosen buildings at university displays the heat consumption amount for each building, as well as heat distribution across the floors of respective selected buildings.

Table 5.1- Heat load consumption of selected buildings. Building Name	Total Heat consumption (MWh/a)	Heat load for square meter of area (MWh/a)	Type of building
Building 19	254.76	72.45	Commercial
Building 34	98.56	121.06	Commercial
Building 28	149.21	96.45	Heavy Laboratory
Weinberghof 07	117.36	64.23	Residential

Table 27 Heat Load Profiles

- Building 19

The heat load profile of building 19 represents the amount of heat that needs to be maintained within a building for comfort requirements. This plot displays the heat load profile of a building with four floors displays and the total heat demand of the building as well as the individual heat loads of each floor. The maximum amount of heat consumption is used in January i.e., 125KWh until March 95KWh, as the outdoor temperatures are cold and as the month's progress and the weather warms up, the heat load decreases to 15KWh. The minimum heat consumption is used from May to September is likely due to the summer season and mild weather, which reduces the demand for heating. From mid-October, the heat load starts to rise again as winter approaches and heating needs gradually increases from 110 to 115KWh.

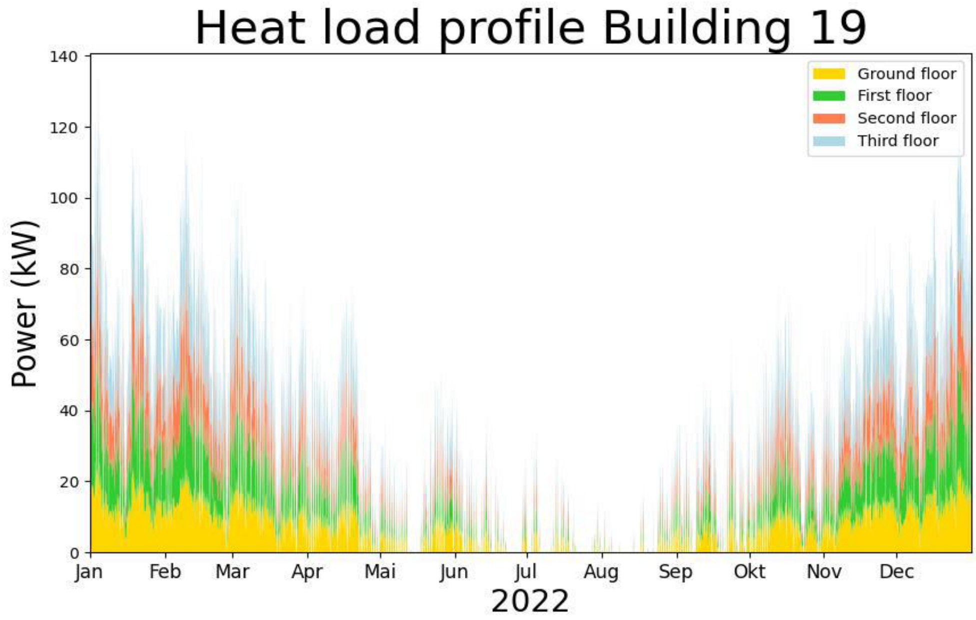

Figure 58 Heat load profile of building 19

This load duration curve is the graphical representation of the amount of heat energy demands met over a certain period of time. It displays the energy demand in KW on the y-axis and time period on x-axis. The highest point representing the maximum demand 134KWh during the specified period of time. The shape of the curve indicates the distribution of energy demand over the period of year, with a steep curve showing a high variability in demand.

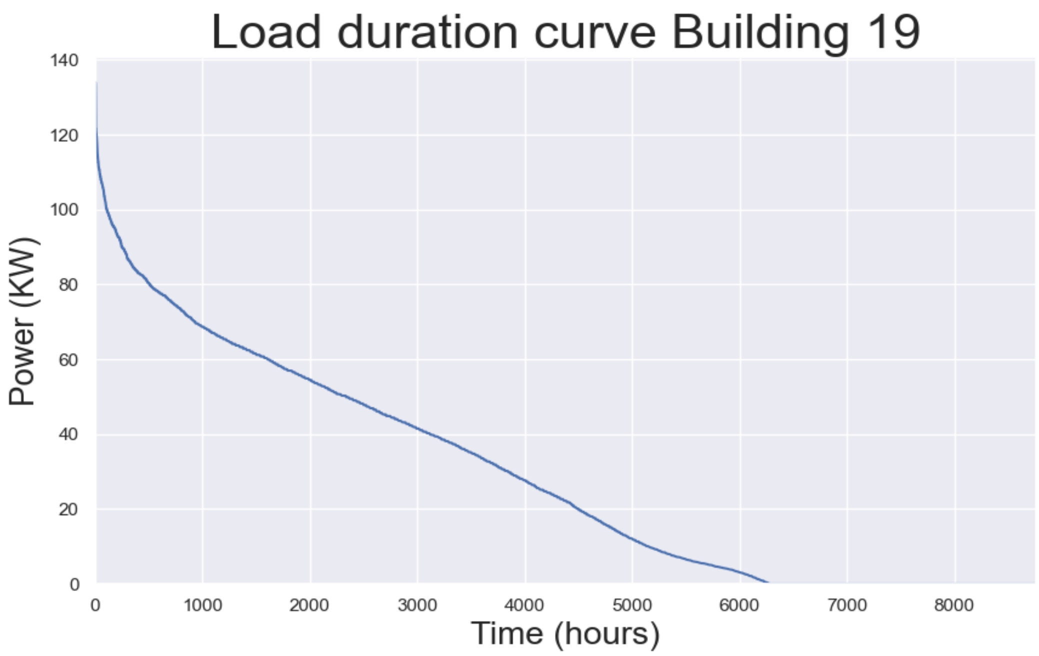

Figure 59 Load duration curve of building 19

- Building 34

The heat load profile of building 34 represents the amount of heat that needs to be maintained within a building for comfort requirements. This plot displays the heat load profile of a building with two floors and the total heat demand of the building as well as the individual heat loads of each floor. The maximum amount of heat consumption is used in January i.e., 51KWh until March 38KWh, as the outdoor temperatures are cold and as the month's progress and the weather warms up, the heat load gradually decreases to 15KWh. The minimum heat consumption is used from May to September is likely due to the summer season and mild weather, which reduces the demand for heating. From mid-October, the heat load starts to rise again as winter approaches and heating needs gradually increases from 20KWh or 48KWh.

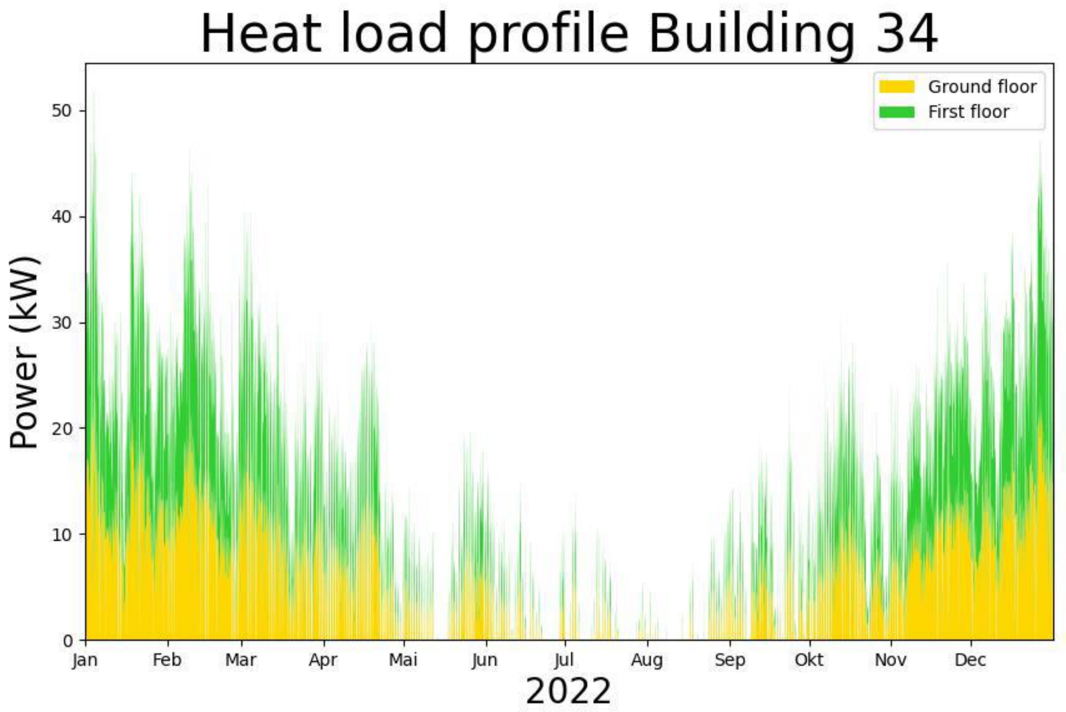

Figure 60 Heat load profile of building 34

This load duration curve is the graphical representation of the amount of heat energy demands met over a certain period of time. It displays the energy demand in KW on the y-axis and time period on x-axis. The highest point representing the maximum demand 51KWh during the specified period of time and the total energy consumed over the specified time period is represented by the area under the curve. The shape of the curve indicates the distribution of energy demand over the period of year, with a steep curve showing a high variability in demand [36].

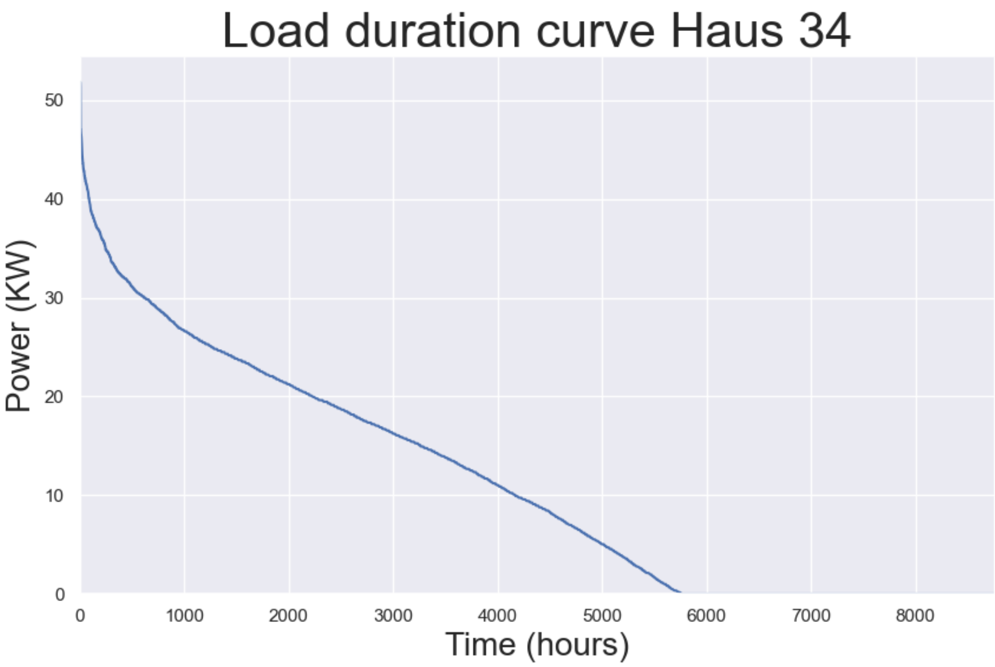

Figure 61 Load duration curve of building 34

- Building 28

The heat load profile of building 28 represents the amount of heat that needs to be maintained within a building for comfort requirements. This plot displays the heat load profile of a building with two floors and the total heat demand of the building as well as the individual heat loads of each floor. The maximum amount of heat consumption is used in January i.e., 78.7KWh until March 45KWh, as the outdoor temperatures are cold and as the month's progress and the weather warms up, the heat load gradually decreases to 5KWh in august. The minimum heat consumption is used from May to September is likely due to the summer season and mild weather, which reduces the demand for heating. From mid-October, the heat load starts to rise again as winter approaches and heating needs gradually increases from 40KWh to 70KWh.

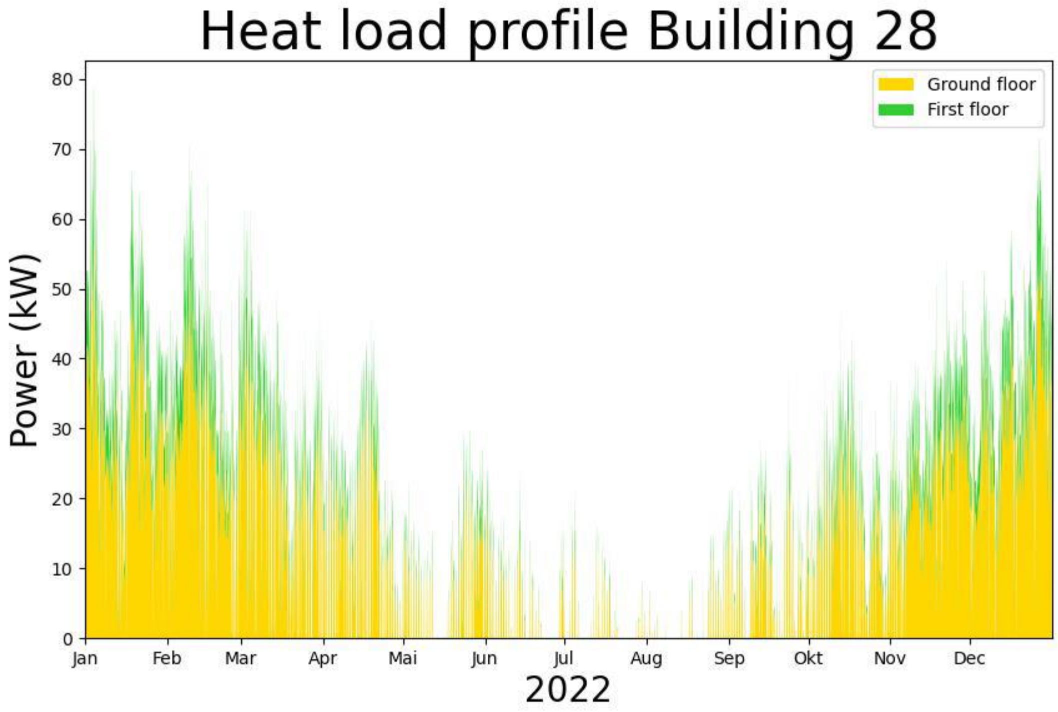

Figure 62 Heat load profile of building 28

This load duration curve is the graphical representation of the amount of heat energy demands met over a certain period of time. It displays the energy demand in KW on the y-axis and time period on x-axis. The highest point representing the maximum demand 78KWh during the specified period of time and the total energy consumed over the specified time period is represented by the area under the curve. The shape of the curve indicates the distribution of energy demand over the period of year, with a steep curve showing a high variability in demand [36].

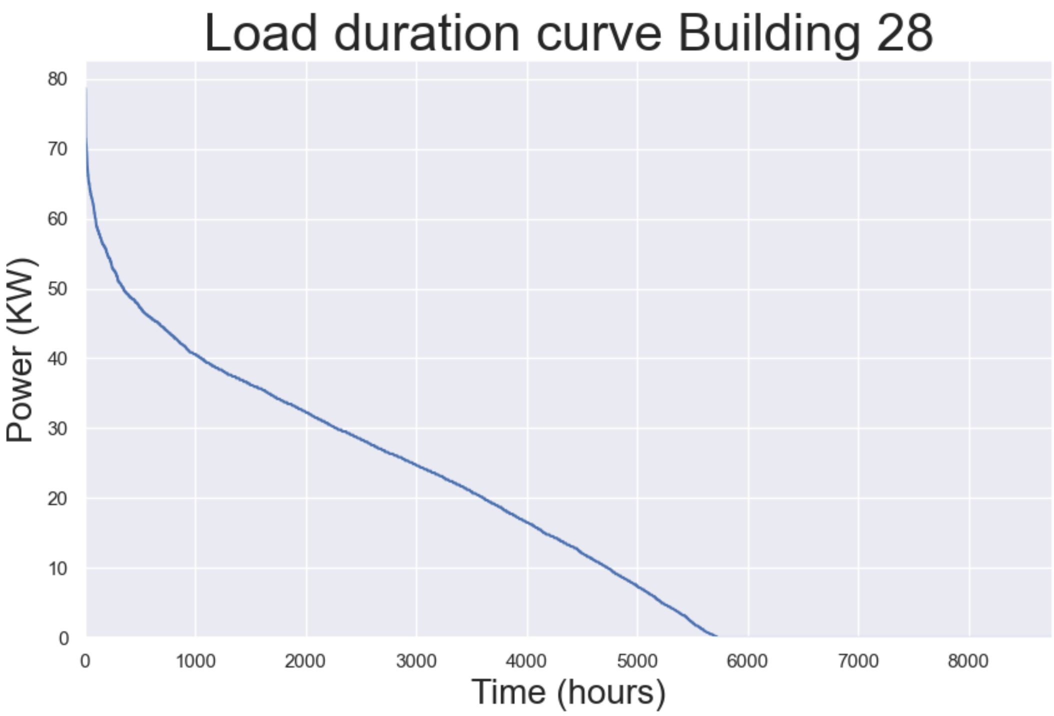

Figure 63 Load duration curve of building 28

- Weinberghof 07

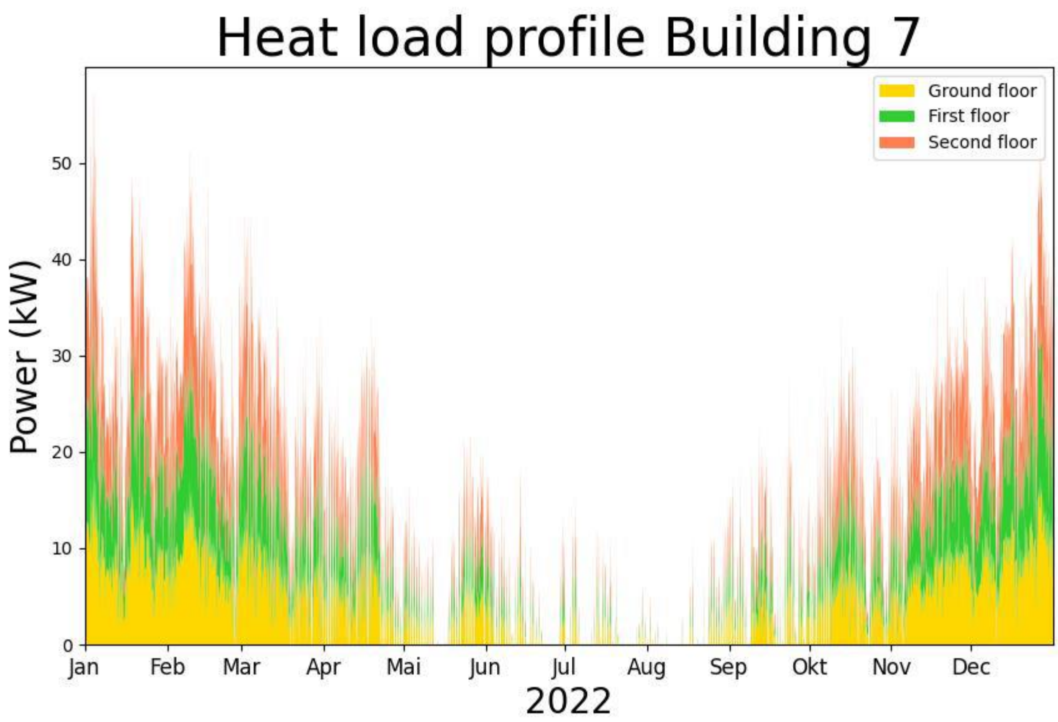

Figure 64 Heat load profile of Weinberghof 07

The heat load profile of weinberghof 07 represents the amount of heat that needs to be maintained within a building for comfort requirements. This plot displays the heat load profile of a building with two floors and the total heat demand of the building as well as the individual heat loads of each floor. The maximum amount of heat consumption is used in January i.e., 57KWh until mid-April 32KWh, as the outdoor temperatures are cold and as the month's progress and the weather warms up, the heat load gradually decreases to 5KWh in august. The minimum heat consumption is used from May to September is likely due to the summer season and mild weather, which reduces the demand for heating and the heat load starts to rise again as winter approaches and heating needs gradually increases from mid-October 38KWh to until December 50KWh.

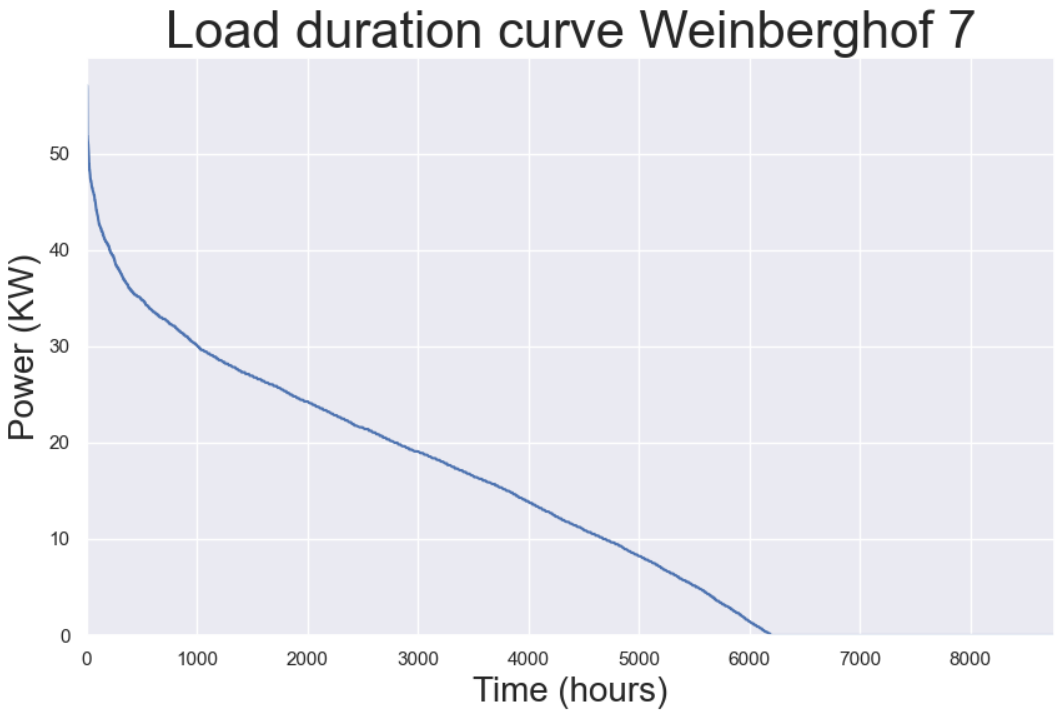

Figure 65 Load duration curve of Weinberghof 07

This load duration curve is the graphical representation of the amount of heat energy demands met over a certain period of time. It displays the energy demand in KW on the y-axis and time period on x-axis. The highest point representing the maximum demand 57KWh during the specified period of time and the total energy consumed over the specified time period is represented by the area under the curve. The shape of the curve indicates the distribution of energy demand over the period of year, with a steep curve showing a high variability in demand.

4.2.3 Comparing Heat Loads of North and South Campuses: Percentage Share

In this discussion, we will be examining the percentage of share of energy consumption attributed to North and South campuses.

Table 28 Area Specific heat quantities

Area	Heat load in (MWh/a)	Percentage of share %
North campus	2030.85	79.0 %
South campus	538.89	20.9 %

As we can see from the table 101 the north campus covers around 79% of the amount of heat of entire university and the south campus covers around 20.9% of heat from entire university. The reason for this is because of large number of buildings are consuming the heat energy.

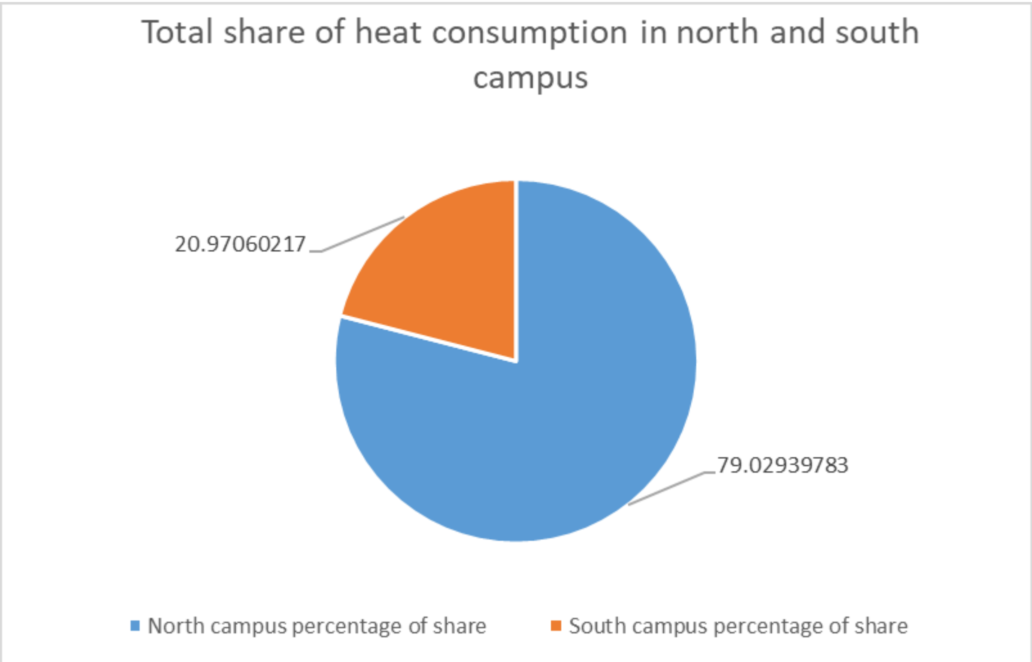

Figure 66 Percentage of share of north and south campuses

- North Campus

Table 29 Heat consumptions of north campus

Building	**Total heat load (MWh/a)**	**Percentage of share %**
Karzer building	235.48	11.6
Building 11	45.37	2.23
Building 12	419.12	20.64
Building 13	11.99	0.59
Building 16	6.77	0.33
Building 18	211.30	10.4
Building 20	217.88	10.73
Weinberghof 14	113.68	5.6
Weinberghof 5	120.07	5.91
Weinberghof 6	150.94	7.43
President's office	85.33	4.2
Building 19	254.76	12.54

Weinberghof 07	117.36	5.78
Weinberghof 13	40.75	2.01
Weinberghof 14	235.48	11.6

As we can see from the above table 102, building 12, 19 and karzer has the maximum amount of heat consumption and the other main consumers in north campus are building 20 and weinberghof 6, 14. The minimum amount of heat consumption is in building 16.

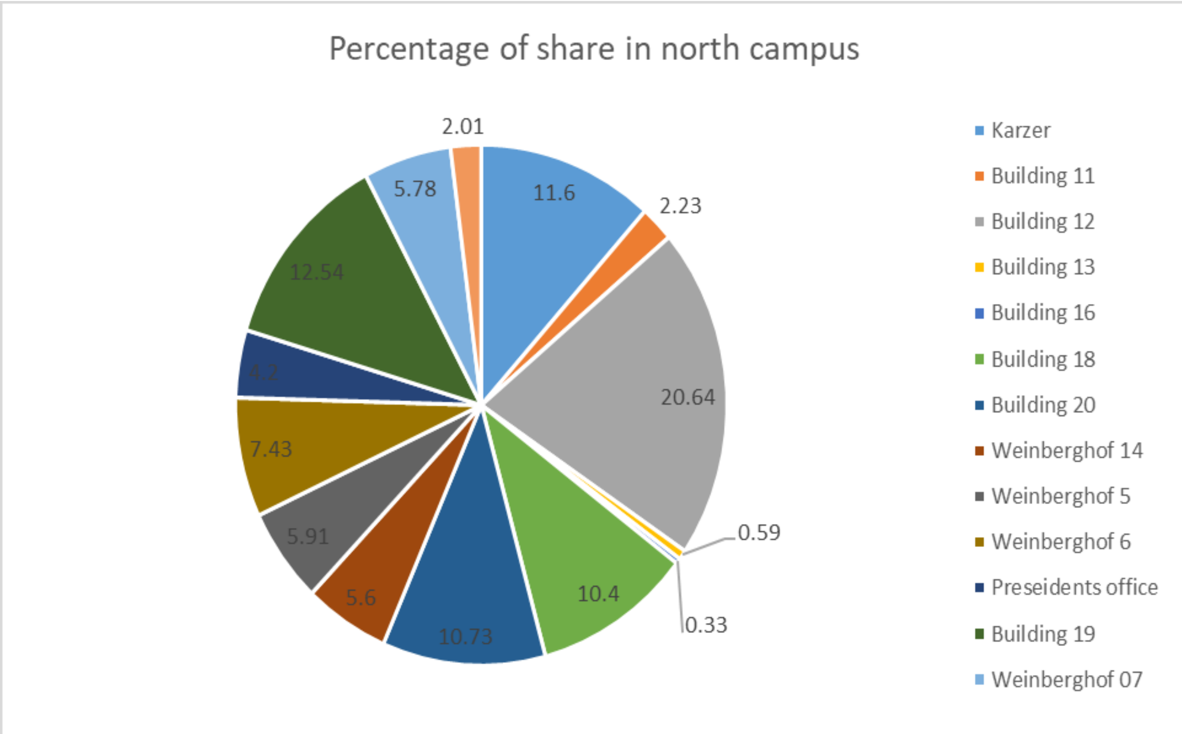

Figure 67 Percentage of share in north campus

- South Campus

Table 30 Heat consumptions of south campus

Building	Total heat load (MWh/a)	Percentage of share %
Building 25	203.75	37.81
Building 35	49.14	9.12
Building 32	38.21	7.09
Building 34	98.56	18.29
Building 28	149.21	27.69

As we can see from the above table 30, building 25 has the maximum amount of heat consumption and the other main consumers in south campus are building 28 and building 34. The minimum amount of heat consumption is in building 32.

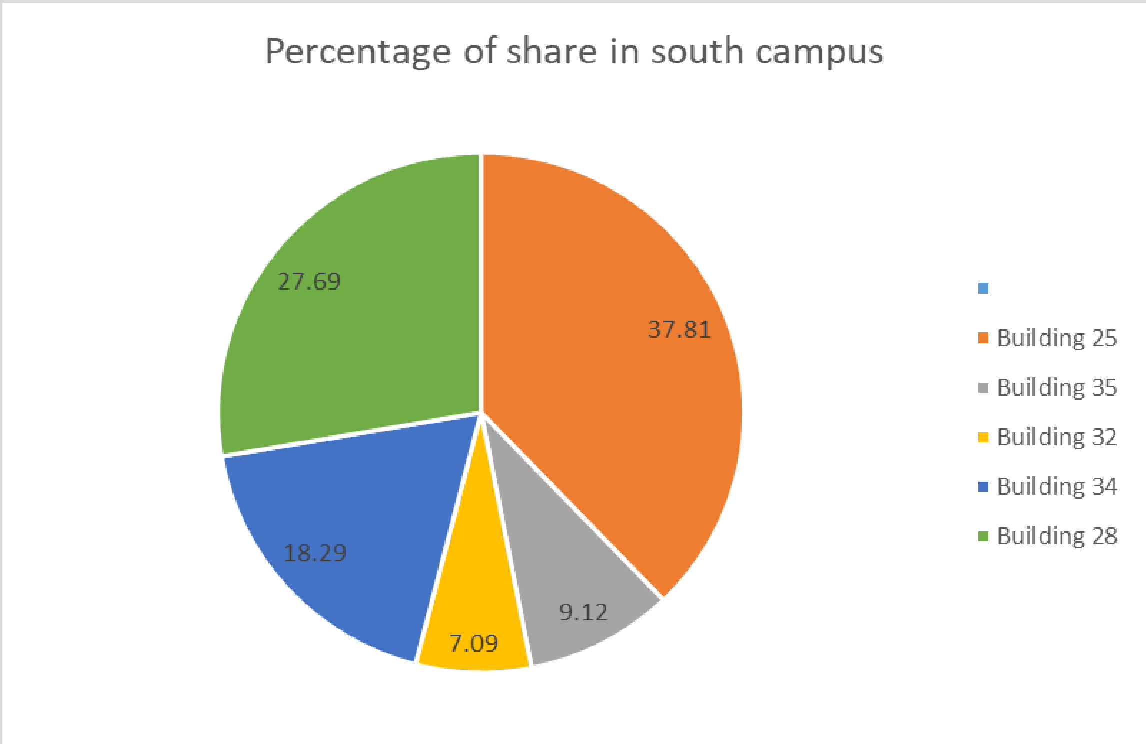

Figure 68 Percentage of share in south campus

Comparison of energy consumption for domestic water heating and space heating

The domestic hot water (DHW) and space heating energy consumption for a specific building or system. The energy consumption data was analyzed to understand the usage patterns and identify areas for improvement. The results of the analysis will provide valuable information to building owners, facility managers, and energy efficiency professionals in their efforts to reduce energy usage and costs. This report will present a comparison of DHW and space heating energy consumption in the university. The X-axis represents the different buildings in university, while the Y-axis shows the energy consumption in megawatt-hours (MWh). It can be seen from the chart that the energy consumption for DHW and space heating varies between the buildings. For example, building 12 has a higher energy consumption for space heating i.e., 418 MWh/a compared to Weinberghof 6, while Weinberghof 6 has a higher energy consumption for DHW 63MWh/a compared to Building 12.

These results will provide valuable insights into the energy consumption patterns for DHW and space heating in different buildings and can inform energy efficiency strategies and initiatives to reduce energy consumption and costs.

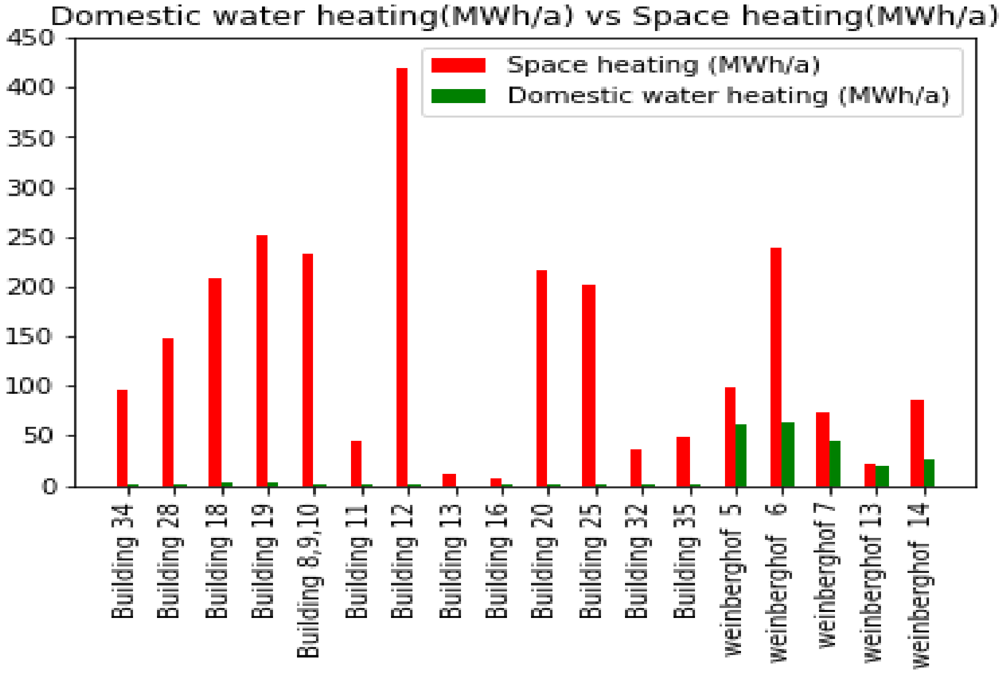

Figure 69 Domestic water heating vs Space heating

4.3 Calibration of Power Consumption and Results: Electricity Supply

Considering the NGA and the type of buildings which is mentioned in Balasoltanov etal. worl, we have calculated the power consumption of each and every building of the university. In the year 2011, there were some buildings which are not mentioned, since their costs of energy consumption are borne by third parties or by the student union [72].

In the year 2011, the total power consumption of the university was 1186.39 MWh and for the years 2012 and 2013 it was 1162.61 MWh and 1172.51 MWh respectively [72]. In the span of ten years there are many modifications/renovations have been done to the university. Apart from that, the addition of the new courses, staff, students, equipment has led to more utilization of energy. We estimated by considering all assumptions which are explained in (methodology electric supply) that, the total consumption for the year 2022 is approximately 1200 MWh.

As mentioned above, the campus is divided into two balance areas: North-campus and South-campus [72]. The total energy utilization of each balance area including street lights and the buildings mentioned in the tables 44 & 45 is calculated.

4.3.1 Comparison between North and South campus: Percentage share

Considering the total consumption of 1200 MWh/a. And by calibrating the consumption of every building and street lights, the percentage share of both balance areas can be calculated.

Table 31 Area specific consumption

Area	(MWh/a)	% Share
North	959.6	79.96
South	240.4	20.04

From the result, it is certain that the North campus requires more energy than the South campus as that area covers a large number of buildings. The North campus has a share of around 80% of total consumption and the remaining 20% of the share is for the South campus.

- South-campus

Table 32 Specific consumption in south-campus

Building/Street lights	MWh/a	% Share of total Consumption
Building 25	43.27	3.60
Building 28	107.74	8.97
Building 34	38.18	3.18
Building 35	8.95	0.74
Building 32	16.43	1.36
Street lights-S	25.80	2.15

As it can be seen in Table 44, highest electrical energy is consumed by building 28, building 35 requires the lowest amount of energy and around 3-4% of total consumption of energy is drawn by buildings 25 and 34 in south-campus area.

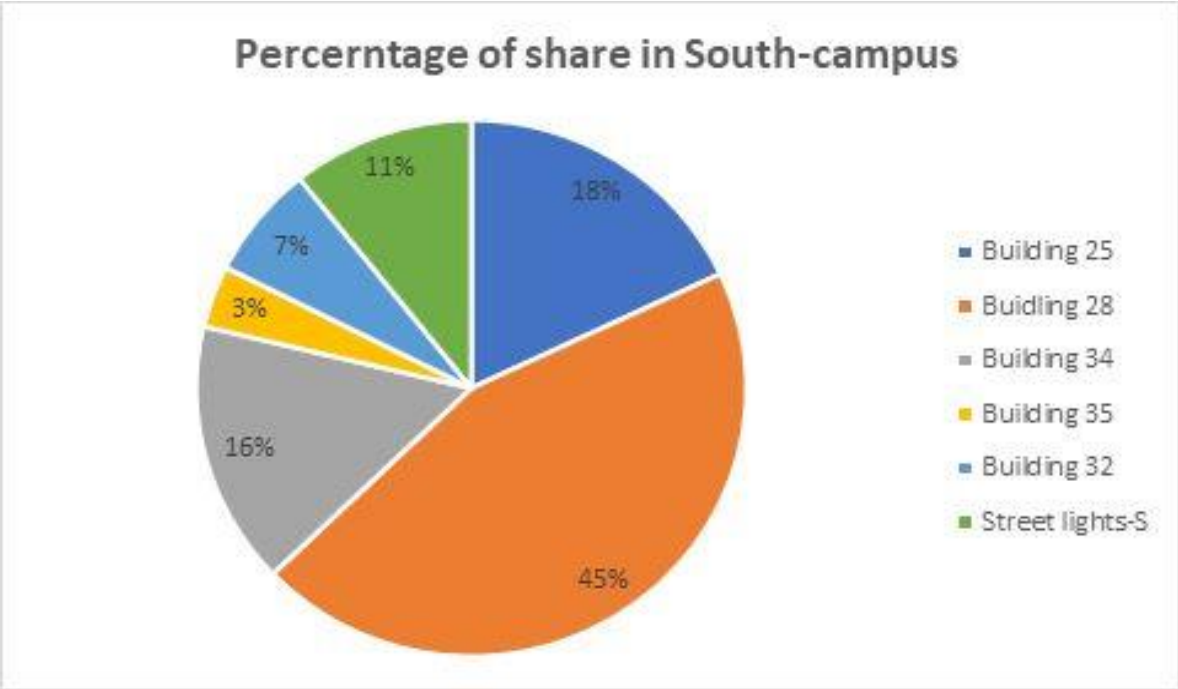

Figure 70 Percentage of share in South-campus

The above figure represents the percentage share of South campus building with respect to its consumption of 240.4 MWh/a which is 20.04% of total consumption.

- North-campus

Table 45 shown below shows the specific consumption in the North campus. Building 18 is the biggest building in our university as it contains the library, administration rooms (SSZ), server rooms as well as seminar halls and lecture rooms. For such reason, it consumes the highest energy with a relative share of around 24% of total consumption. Furthermore, around 1/20 of the total energy of the South campus is drawn by the student dorms.

Table 33 Specific consumption in north-campus

Building/Street lights	MWh/a	% Share of Total Consumption
Weinberghof 7/7a	74.58	6.21
Weinberghof 14/14a	63.19	5.26
Weinberghof 13	38.76	3.23
Building 9	14.28	1.19
Building 10	25.78	2.14
Building 5	84.26	7.02
Building 6	77.68	6.47
Building 8	11.22	0.93
Building 11	31.35	2.61
Building 12	50.47	4.20
Building 13	2.64	0.22
Building 14	28.72	2.39
Building 16	22.07	1.83
Building 18	280.28	23.35

Building 19	78.33	6.52
Building 20	28.13	2.34
Building 22	21.65	1.80
Street lights-N	26.11	2.17

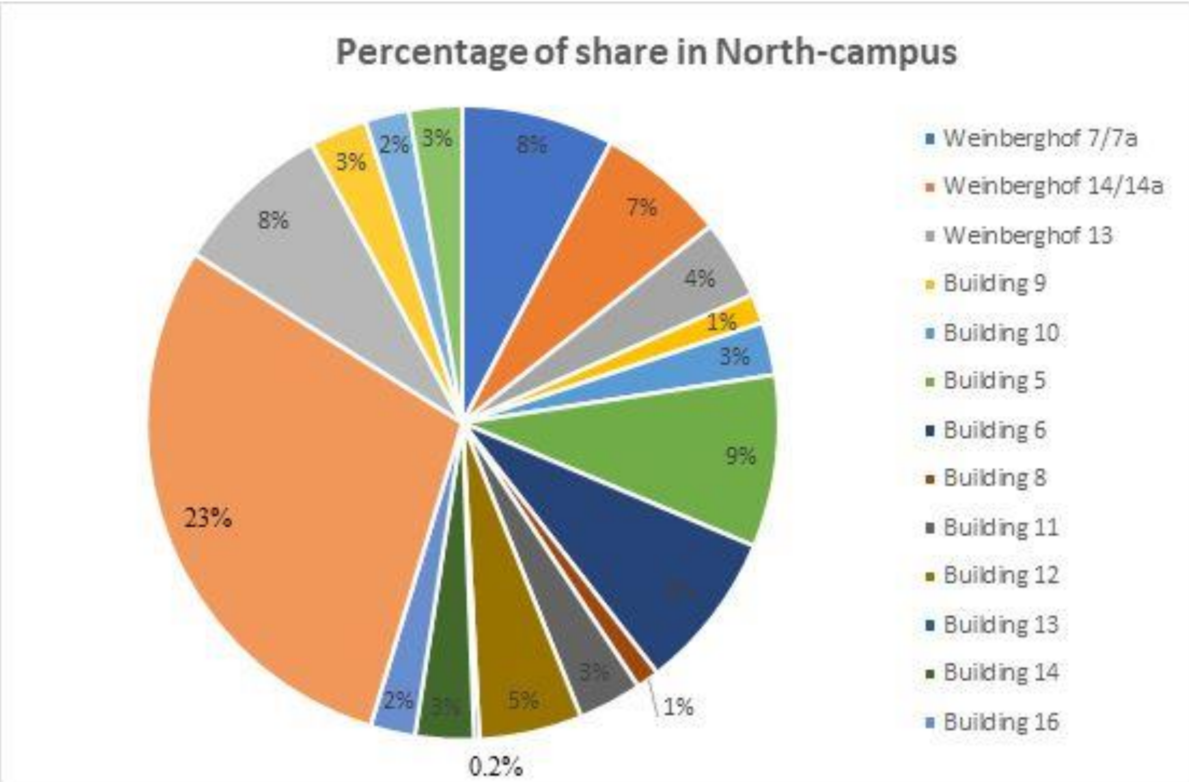

Figure 71 Percentage of share in North-campus

The above figure represents the percentage share of North campus building with respect to its consumption of 959.6 MWh/a which is 79.96% of total consumption.

- Street lights

The street lights are being kept on in the university only when there is dark. In other words, from the evening till the next morning. As can be seen from Table 45 and Table 46, the street lights of both the North and South campus are consuming almost the same share of energy of around 2% of total consumption.

- Results

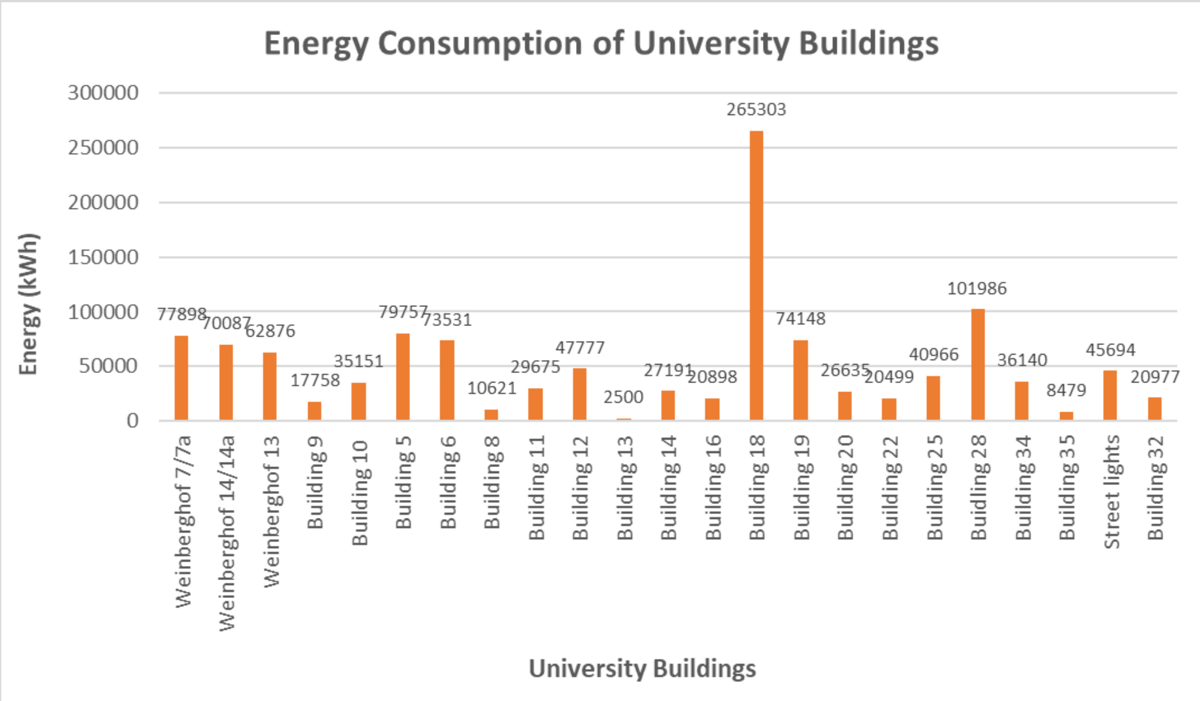

Figure 72 Energy Consumption of buildings of HSN

Above graph illustrate the annual energy consumption for each building of our university. It can be seen that the energy consumption varies between the buildings. For example, building 18 has a huge energy consumption i.e., 265 MWh/a compared to other buildings.

As a result, we have an understanding of electrical load profile calculations, which include examining patterns of power use over a predetermined time frame to establish the load profile of a certain electrical system in HSN Campus. It can be used to identify the peak demand periods by examining electrical load profiles, and they may utilize this knowledge to design capacity effectively, implement load shedding, and maintain grid stability. It also be used to scrutinize places where energy usage can be reduced, which might result in considerable cost savings and a decrease in greenhouse gas emissions. This may be done by locating inefficient areas of use, fixing them, utilizing in place energy-saving techniques, and motivating people to employ more energy-efficient behaviors. It is important for us to keep generating and employing new technology that can help us better control our energy consumption and have a good influence on the environment as long as we continue to depend on power for our everyday requirements.

4.4 Calculation of Potential determination

4.4.1 Solarrechner Website

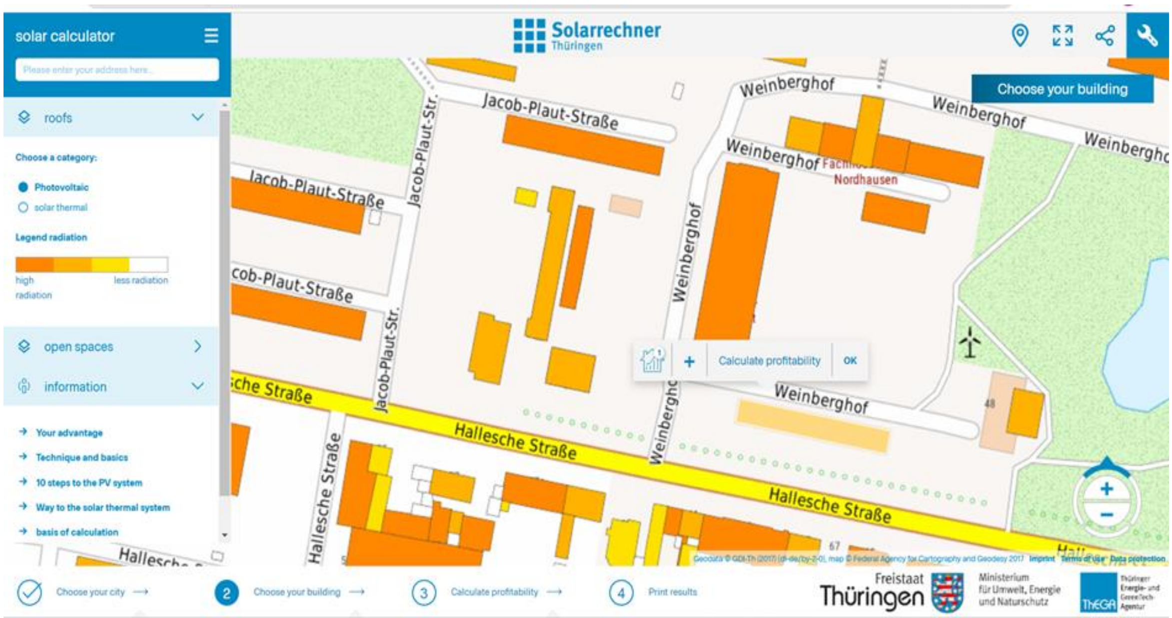

Figure 73 Solarrechner Website

The calculation begins with entering the address where we have to do the calculation. Once the location is shown as spatial view, one can select the building roof in which we have to do the calculation. The website also has the option to select whether we have to install photovoltaic or solar thermal systems.

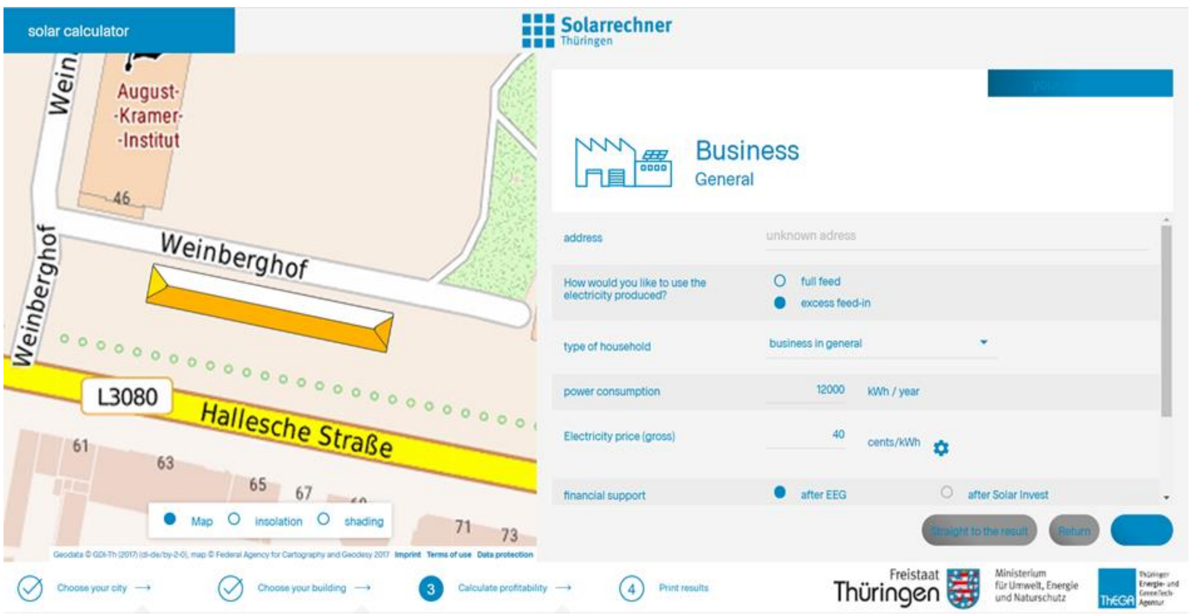

Figure 74 Solarrechner Calculation parameters

On the figure, we can observe the image of the selected roof divided into different sections based on irradiation they are receiving. On the right side, we can adjust the requirements of consumption. There is also option for choosing the type of view required based on different maps. Now the final result can be printed.

Figure 75 Configured PV

The result gives information about possible outcomes, number of panels, cost, CO_2 emissions and other data. There is also some graphical representation about the output at different time of the year.

Figure 76 Graphical representations of Solarrechner parameters

For the purpose of installation of photovoltaic and solar thermal systems on the building rooftops, there are a number of buildings in the university campus. But due to the availability of required irradiation, angle of tilt, geometry, cost effectiveness based on the Solarrechner. To start with we choose 5 buildings as shown in Figure. These buildings were found to give more space for installation with required operating conditions The five buildings chosen were:

- Building 19
- Building 20
- in.RET
- Studienkolleg
- Building 25

Figure 77 Chosen Buildings for Solarrechner

- Building 19

Table 34 Building 19 Specifications

Building No.	Roof No.	Roof area m^2	Roof tilt (degree)	Irradiation (%)	Shadow (%)	Azimuth angle	Roof direction
19	19.1	629.51	1.13	86	2.3	193	South-West
	19.2	65.96	0.98	86.5	1.8	193	South-West
	19.3	65.96	0.36	87	0.4	193	South-West

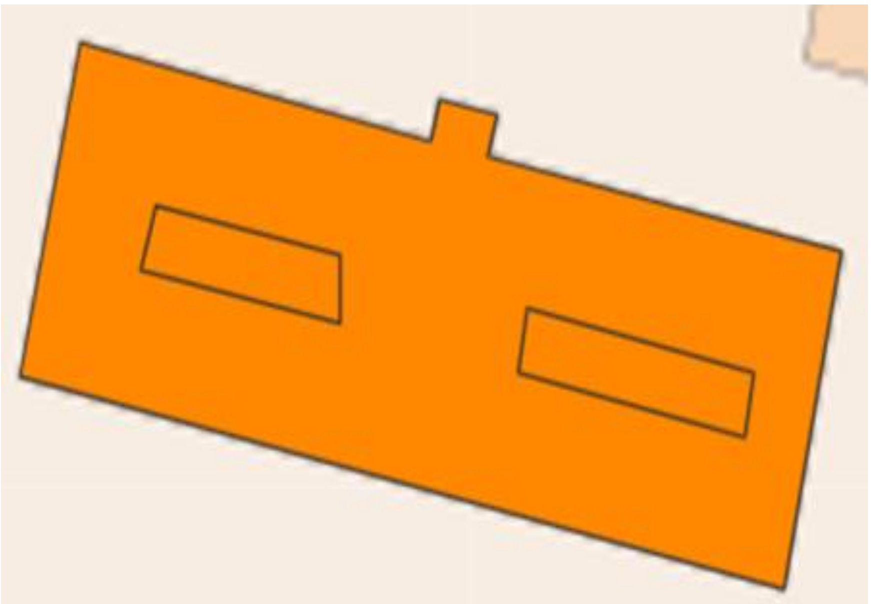

Figure 78 Building 19 Solarrechner and image

- Building 20

Table 35 Building 20 Specifications

Building No.	**Roof No.**	**Roof area m^2**	**Roof tilt (degree)**	**Irradiation (%)**	**Shadow (%)**	**Azimuth angle**	**Roof direction**
20	20.1	515.24	0.17	87	0.8	193	South-West

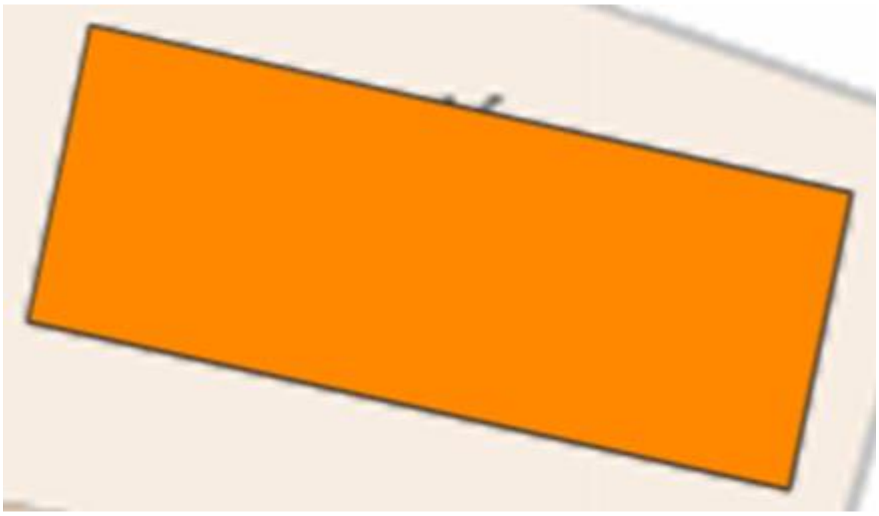

Figure 79 Building 20 Solarrechner and image

- Building 34 (in.RET)

The below table presents the results of the Solarrechner calculation of building 34. Upon inspection of the data, it can be noted that three out of four sections of the building roof are suitable for photovoltaic (PV) or solar thermal installations. The data suggests that the building has a good rooftop solar potential due to the high irradiation percentage and the favorable roof directionz

Table 36 Building 34 specifications

Building No.	Roof No.	Roof area m^2	Roof tilt	Irradiation (%)	Shadow (%)	Azimuth angle	Roof direction
34	34.1	274.2	35.63	88.3	11.5	191	South-west
	34.2	16.8	34,38	84.2	1.6	281	South-east
	34.3	19.8	33.47	75.6	4.3	101	North west

Figure 80 Building 34 Solarrechner and image

- Building 12 (Studienkolleg)

Table 37 Building 12 Specifications

Building No.	Roof No.	Roof area m^2	Roof tilt	Irradiation (%)	Shadow (%)	Azimuth angle	Roof direction
12	12.1	37.81	37.62	8888 81.2	0.2	274	North-West
	12.2	278.05	33.99	98.7	1.3	184	South-West
	12.3	127.37	37.38	83.1	0.1	94	South-East
	12.4	87.51	37.21	80.2	0.4	274	North-West

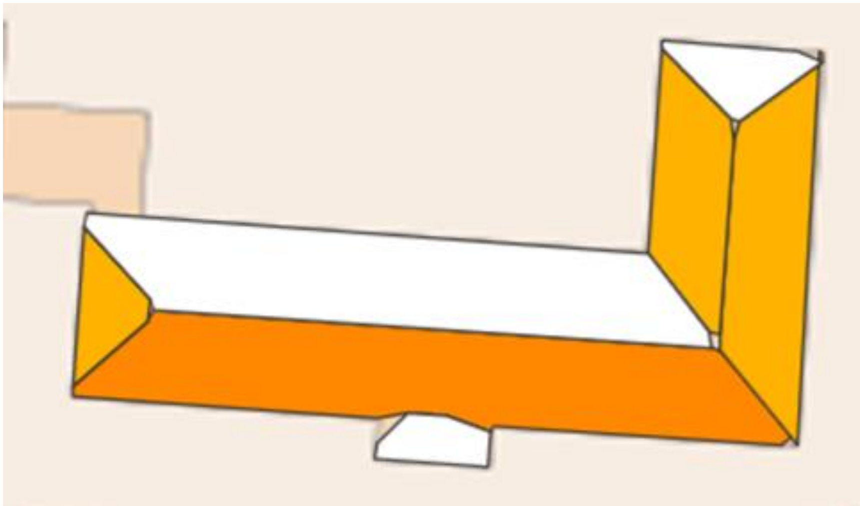

Figure 81 Building 12 Solarrechner and image

- Building 25

Table 38 Building 25 specifications

Building No.	Roof No.	Roof tilt	Irradiation (%)	Shadow (%)	Azimuth angle	Roof direction	Roof area CAD [m^2]
25	25.1	0.3	82.7	5.2	192	South-west	77.75
	25.2	0.3	82.7	5.2	12	North-east	77.75
	25.3	19	96.6	0.5	192	South-west	218.74
	25.4	19.19	72.7	0.7	12	North-east	152.6
	25.5	19.35	81.9	1.9	282	North-west	54.87
	25.6	19.68	85.9	2	102	South-east	54.87
	25.7	0.25	82.2	5.3	192	South-west	175.15
	25.8	0.25	82.2	5.3	12	North-east	175.15
	25.9	19.06	83.6	0.3	102	South-east	25
	25.10	19.02	87.9	0.3	282	North-west	25

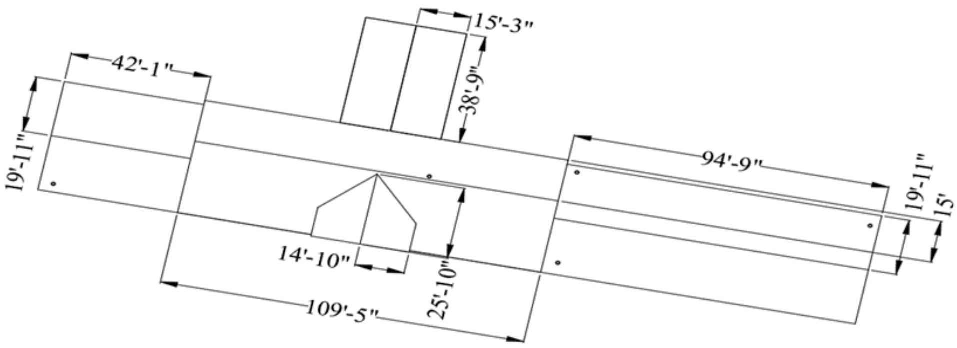

Figure 82 Top view of Building 25

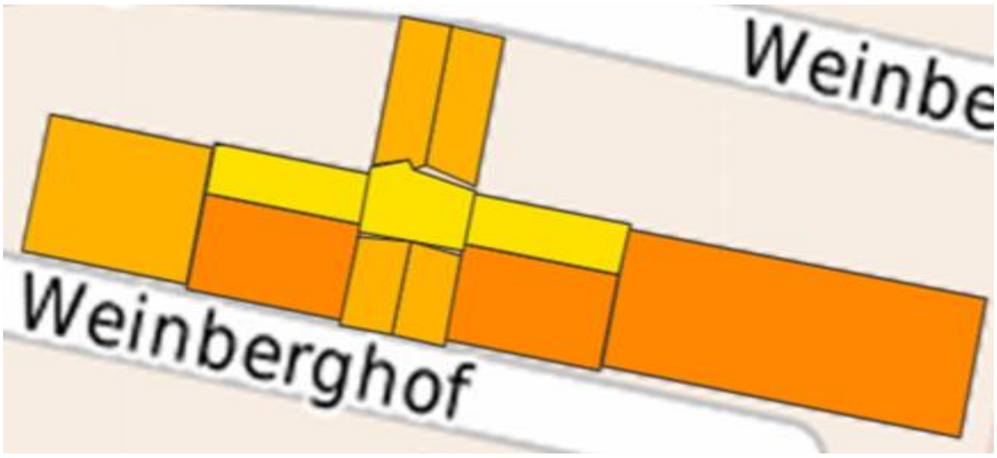

Figure 83 Building 25 Solarrechner and image

As per the data calculation (From Table 22) from Solarrechner the roof top of the building 25 is not accurate compared to the actual building structure or geometry. Hence, additionally a CAD drawing of the rooftop is necessary and drawn as shown in figure (32-37). corresponding areas of the rooftop were calculated and included in the table 18-22**.** This makes the Solarrechner less dependable.

4.4.2 Results of Potential Determination

Table 39 Inverter Sizing

Building name	Number of Panels	Inverter size				Inverter company
		Panels per string	Strings per Inverter	P_{DC} (kW)	P_{AC} (kW)	
Building 19	90	10	9	33.3	30	Advanced Energy Industries
Building 20	90	10	9	33.3	30	Advanced Energy Industries
Building 34	108	12	9	39.960	40.05	Canadian Solar
Building 25 sys.1	96	8	12	35.52	35	Advanced Energy Industries
Building 25 sys.2	84	12	7	31.08	30	Advanced Energy Industries
Building 12	104	8	13	38.48	36	SMA America

- Building 19

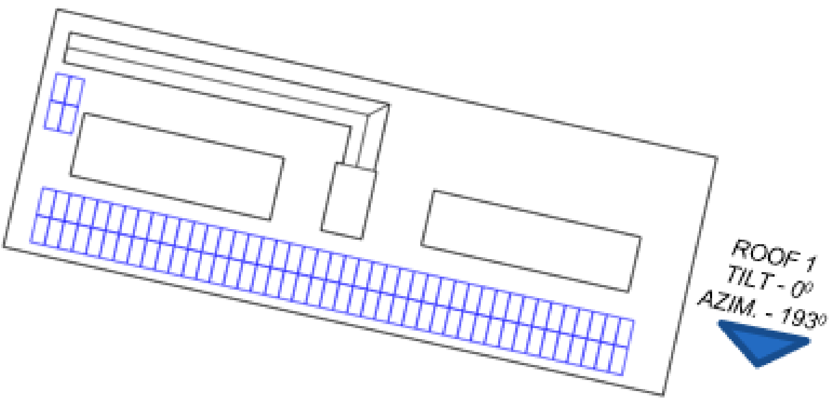

Figure 84 Panel layout of Building 19

Project Description:

- 90 x Hanwha Q cells 370 W modules
- System size: 33.30 kW DC STC
- Annual energy yield: 42.37 MWh/a
- Array area: Roof 1: 175.17 m²

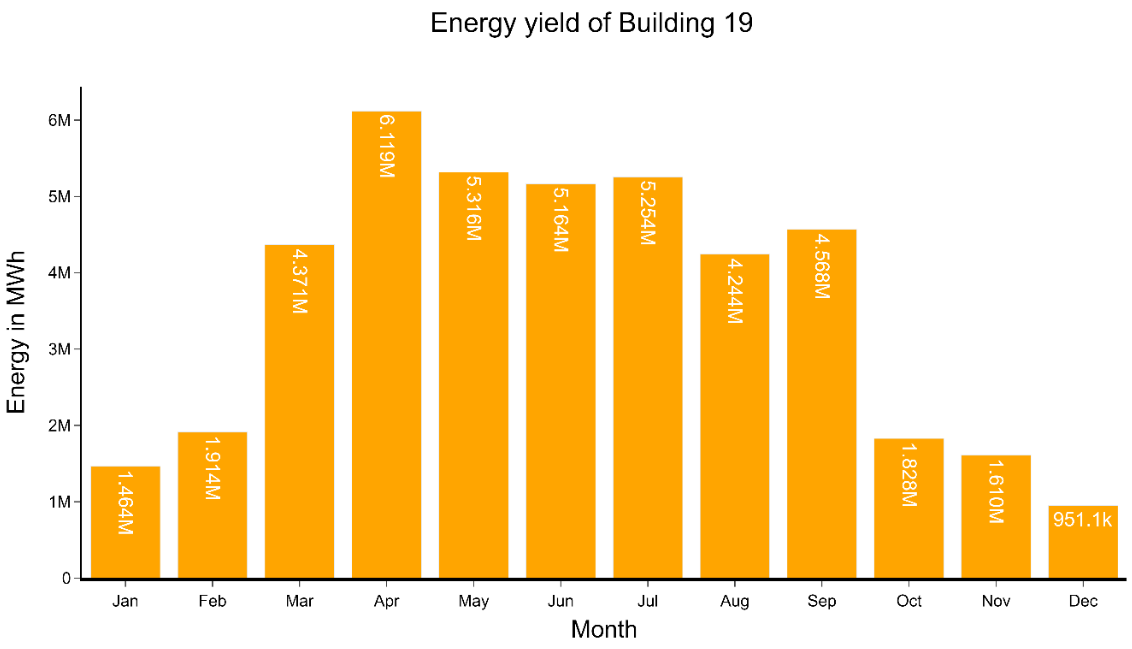

Figure 85 Energy yield for one year (Building 19)

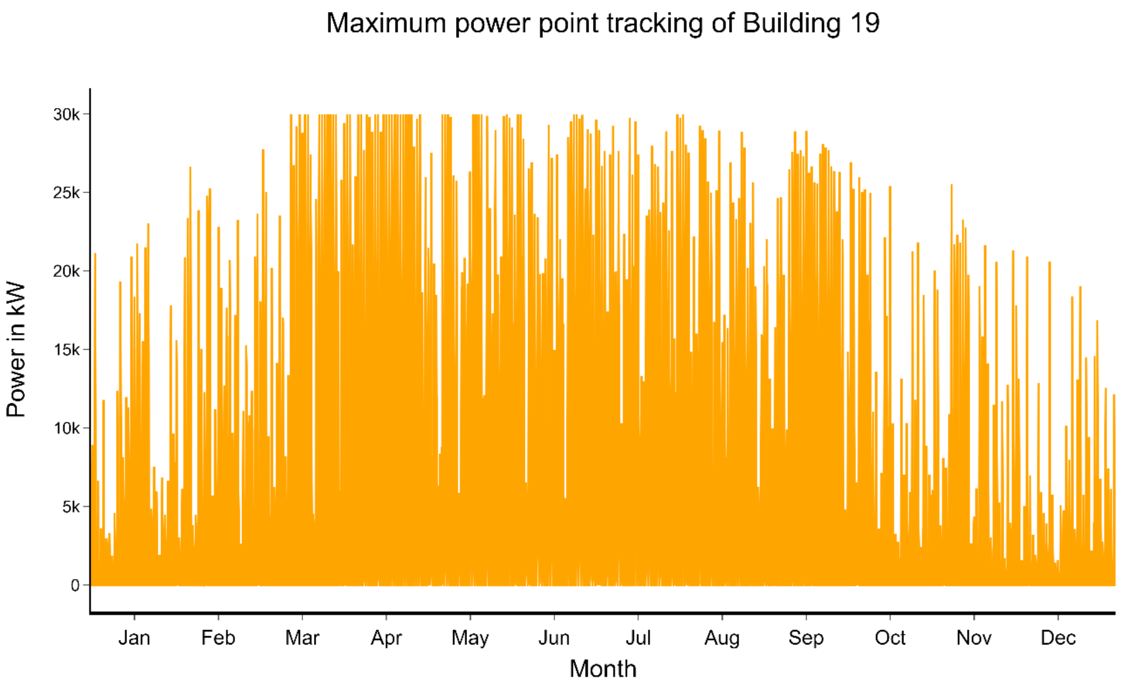

Figure 86 MPP tracking (Roof 1 & 3 of Building 19)

- Building 20

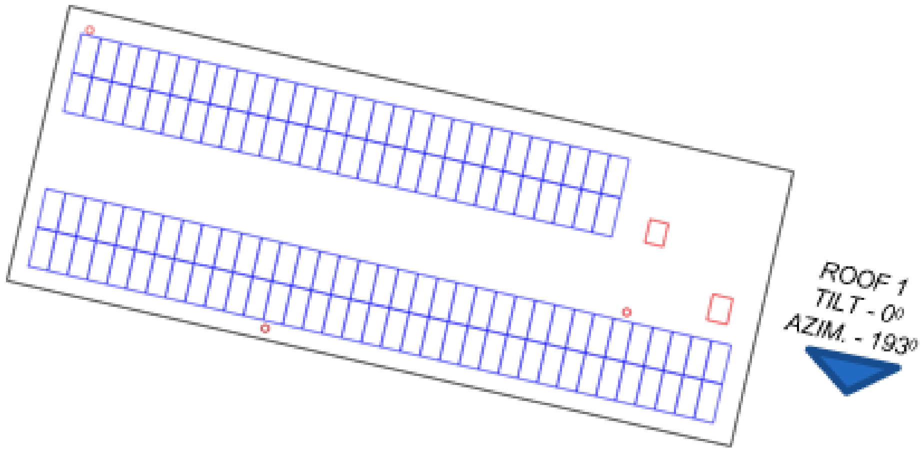

Figure 87 Panel layout of Building 20

Project Description:

- 90 x Hanwha Q cells 370 W modules
- System size: 33.30 kW DC STC
- Annual energy yield: 42.37 MWh/a
- Array area: Roof 1: 175.17 m^2

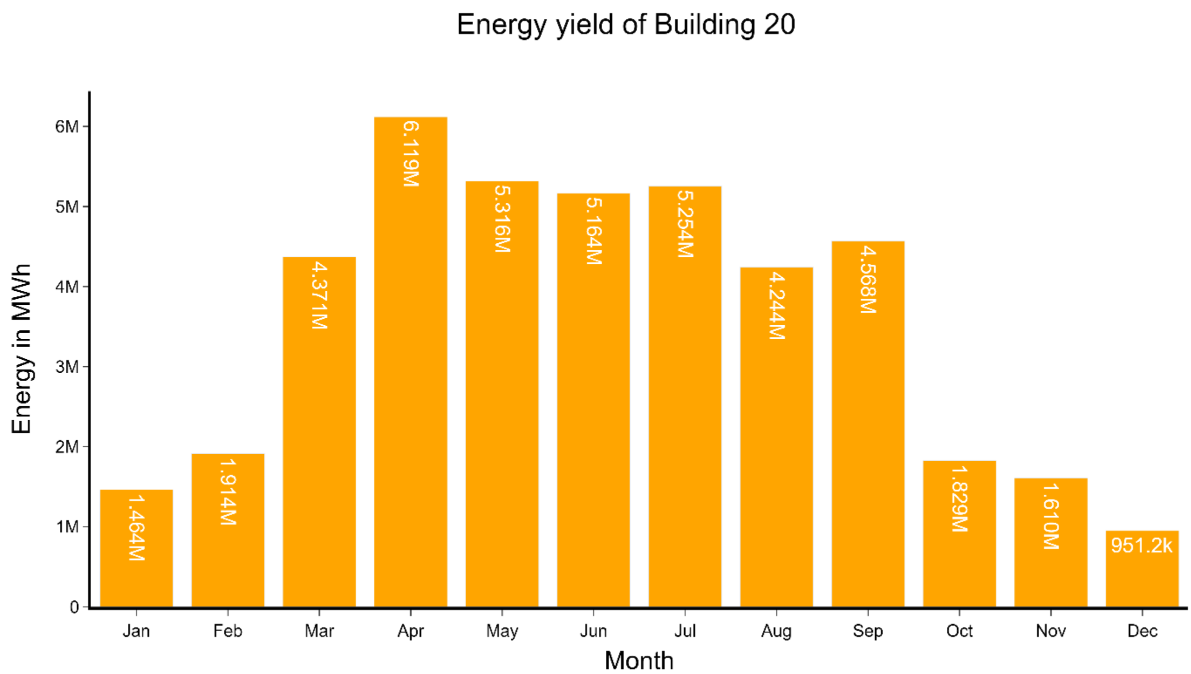

Figure 88 Energy yield for one year (Building 20)

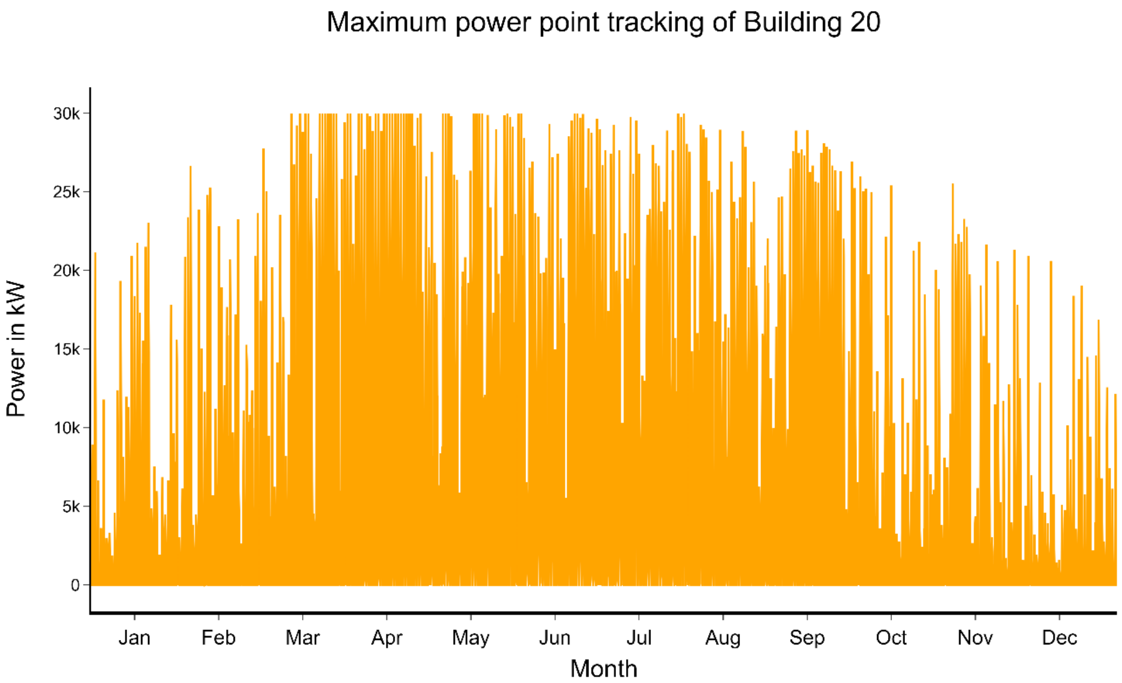

Figure 89 MPP tracking (Building 20)

- Building 34

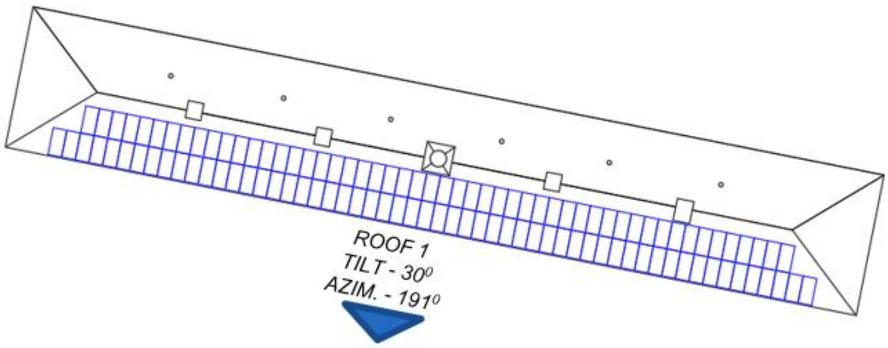

Figure 90 Panel layout of Building 34

Project Description:

- 108 x Hanwha Q cells 370 W modules
- System size: 39.96 kW DC STC
- Annual energy yield: 52.48 MWh/a
- Array area: Roof 1: 209.52 m^2

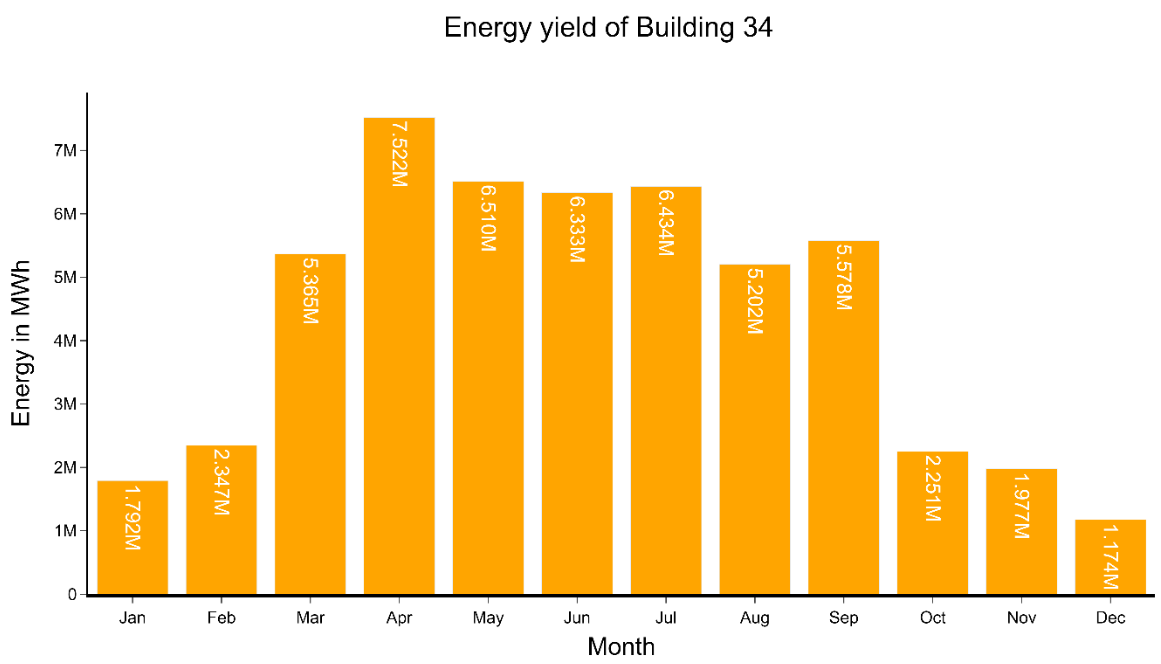

Figure 91 Energy yield for one year (Building 34)

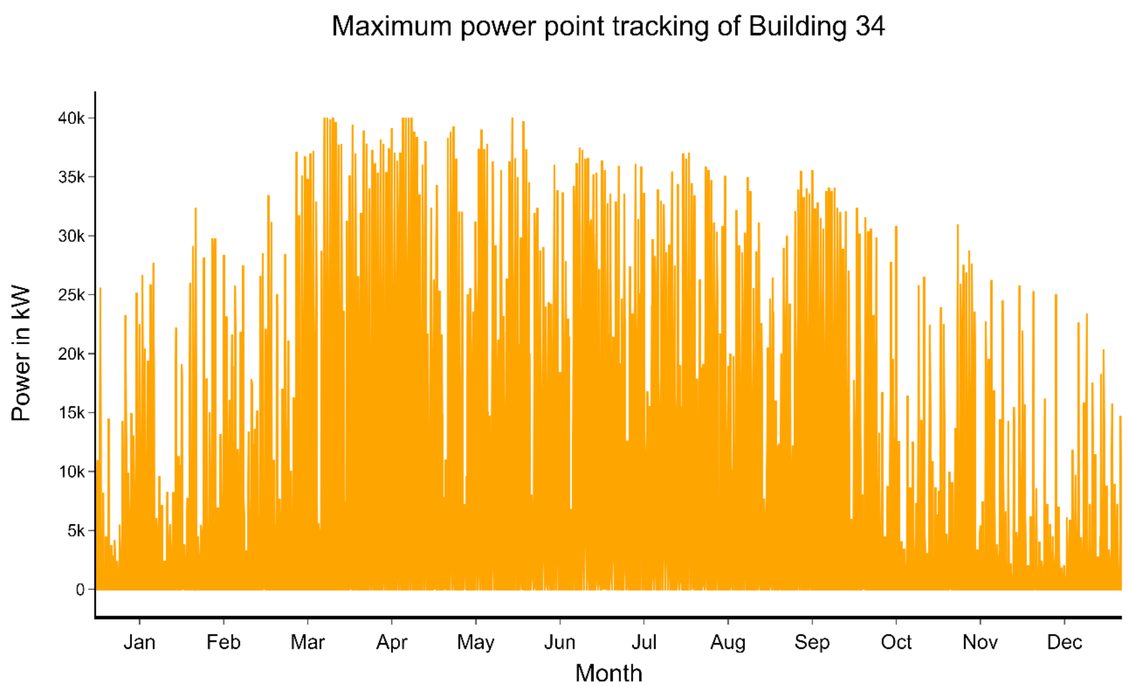

Figure 92 MPP tracking (Building 34)

- Building 25

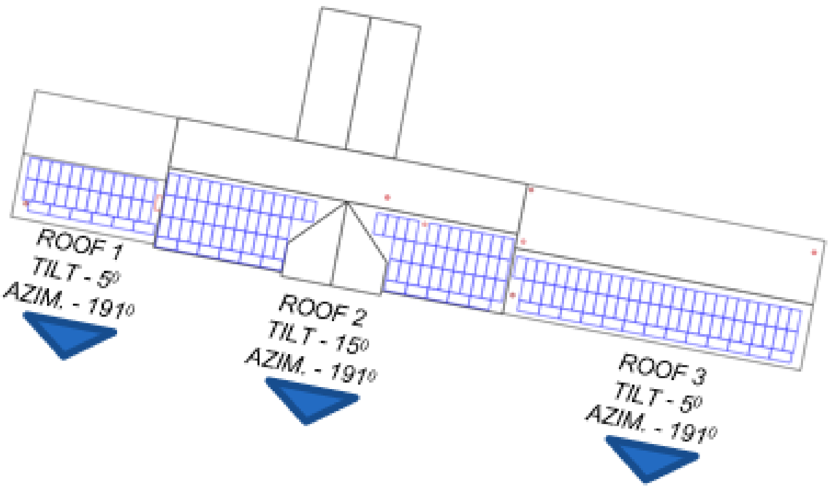

Figure 93 Panel layout of Building 25

Project Description:

- 179 x Hanwha Q cells 370W modules
- System size: 66.23 kW DC STC
- Annual Energy: 90.47 MWh/a
- Array area: Roof 1: 58.4 m^2
- Array area: Roof 2: 140.14 m^2
- Array area: Roof 3: 128.45 m^2

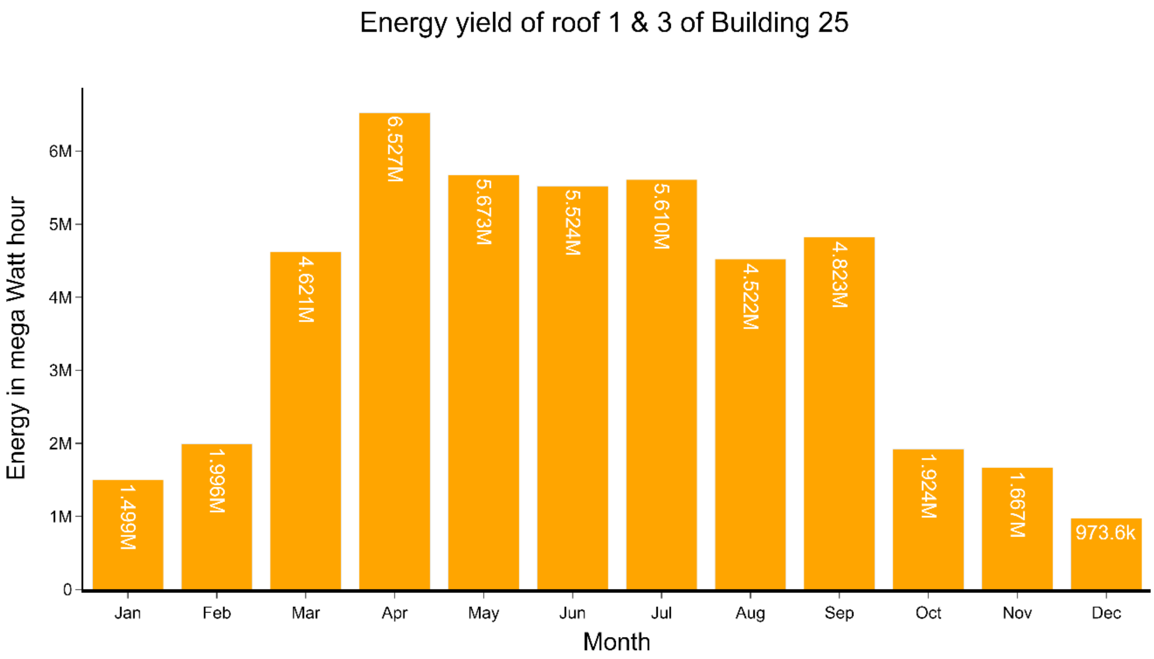

Figure 94 Energy yield for one year (Roof 1 &3 – building 25)

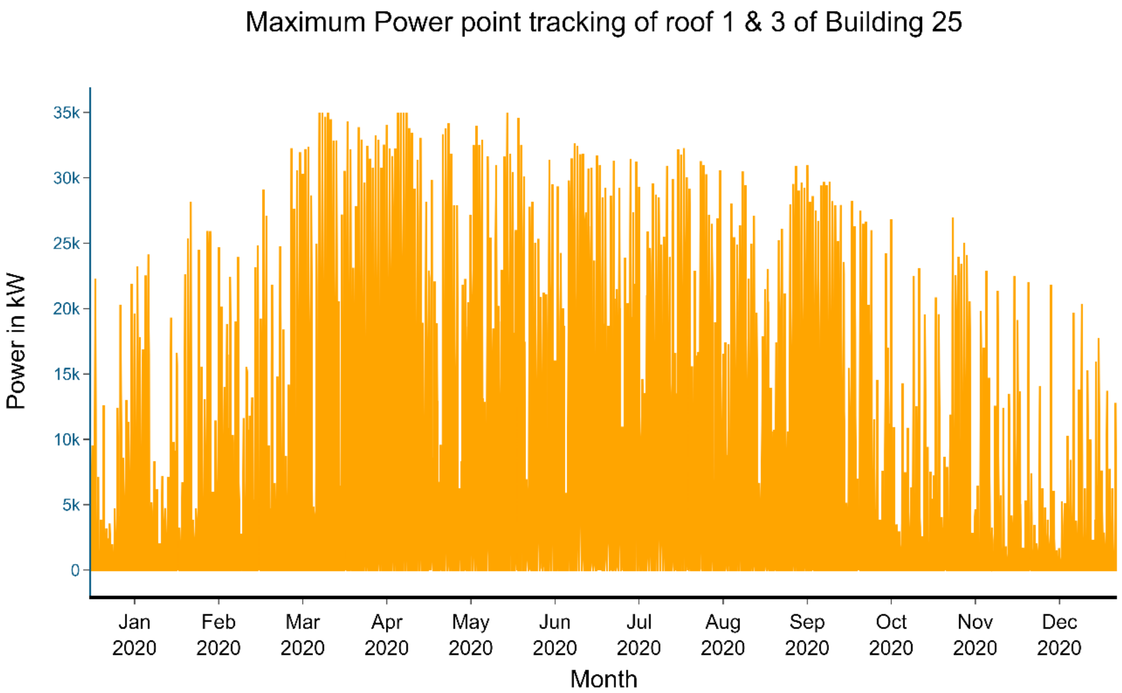

Figure 95 MPP tracking (Roof 1 & 3 - Building 25)

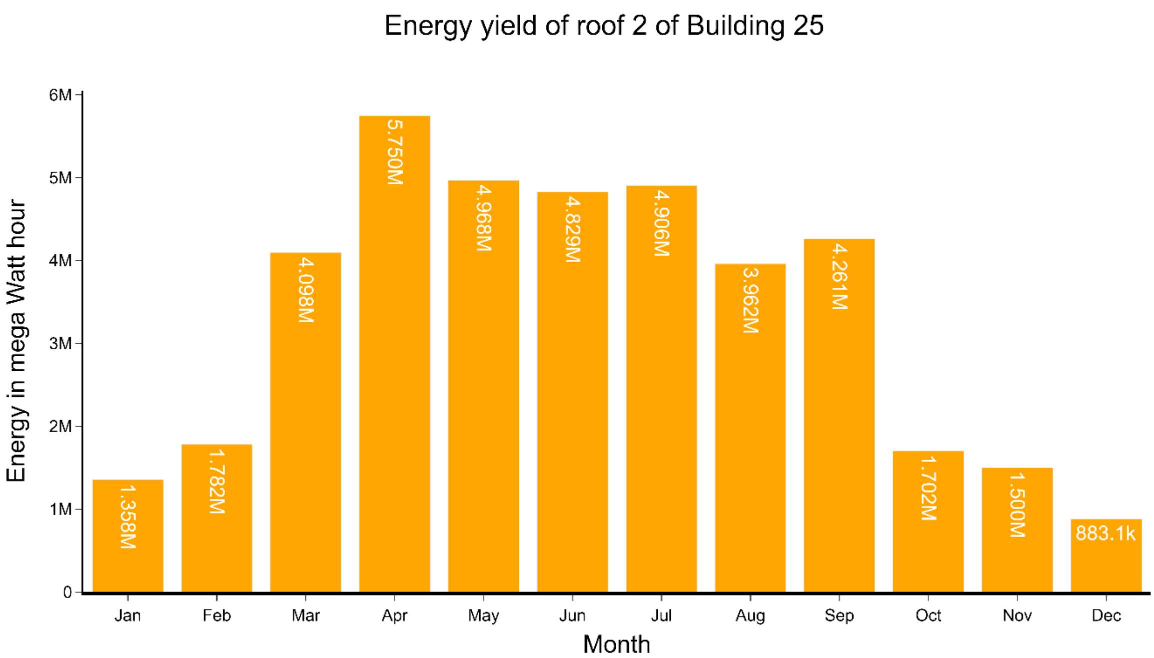

Figure 96 Energy yield for one year (Roof 2 – building 25)

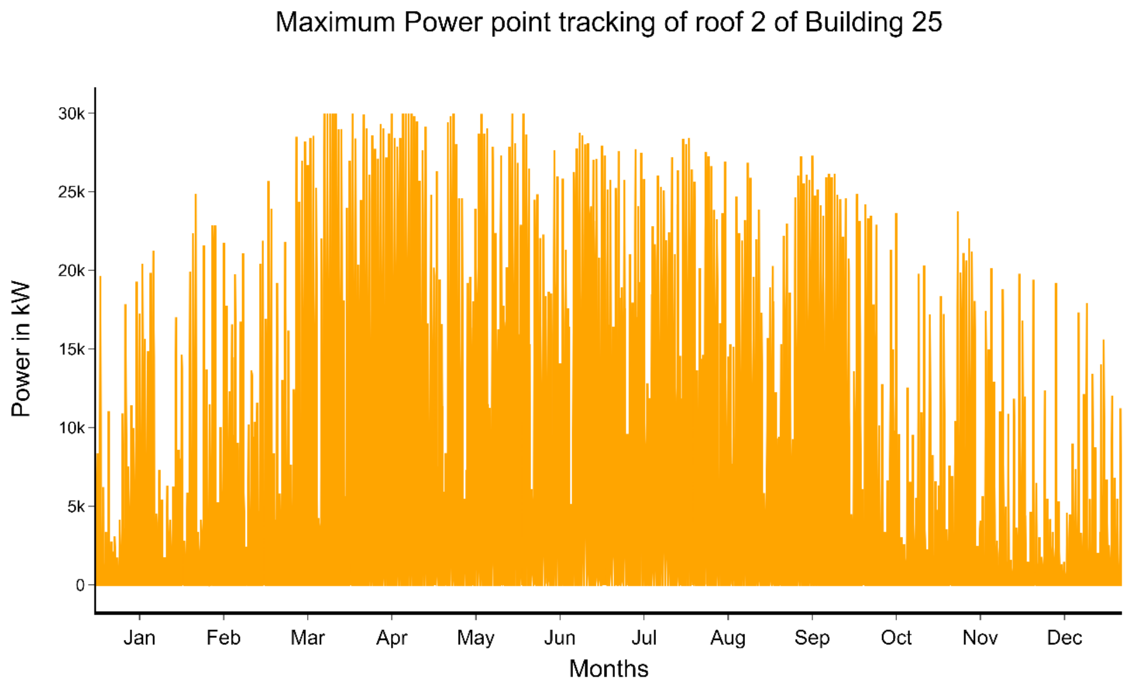

Figure 97 MPP tracking (Roof 2 - Building 25)

- Building 12

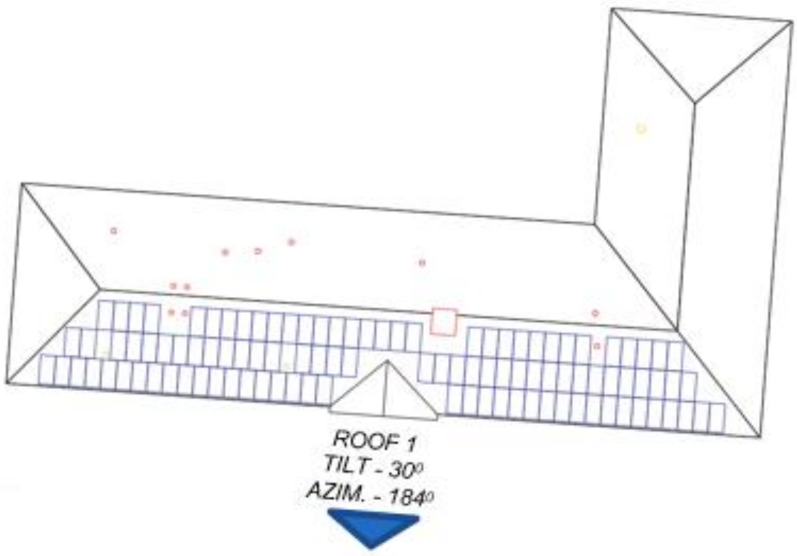

Figure 98 Panel layout of Building 12

Project Description:

- 104 x Hanwha Q cells 370W modules
- System size: 38.48 kW DC STC
- Annual energy: 49.63 MWh/a

- Array area: Roof 1: 202.42 m^2

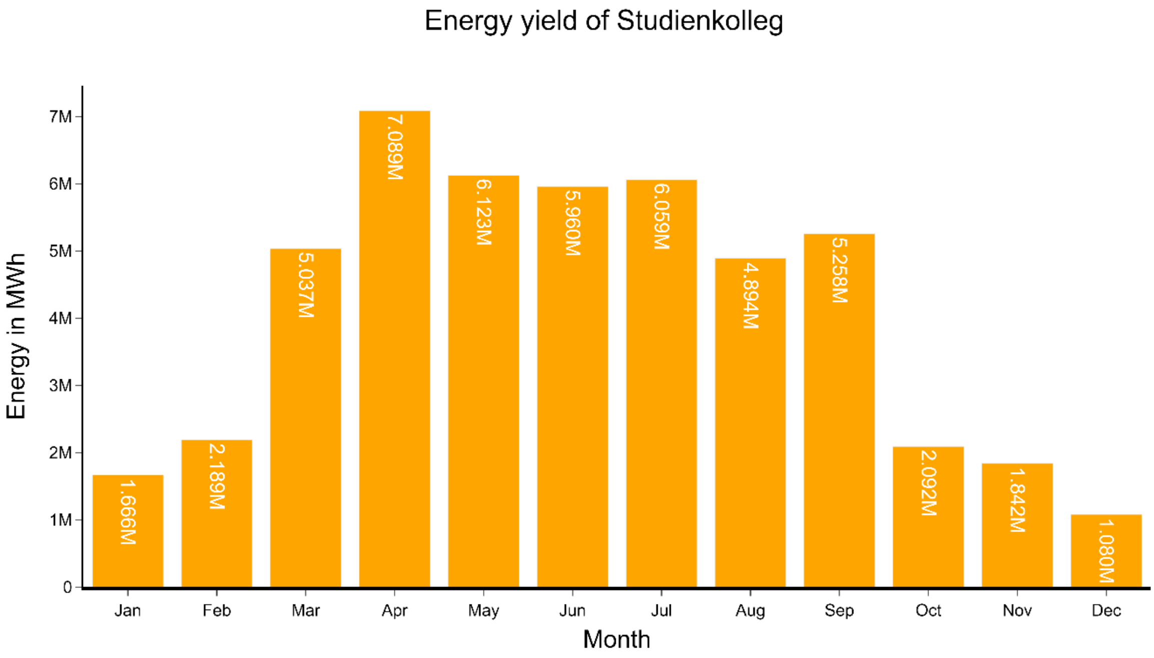

Figure 99 Energy yield for one year (Studienkolleg)

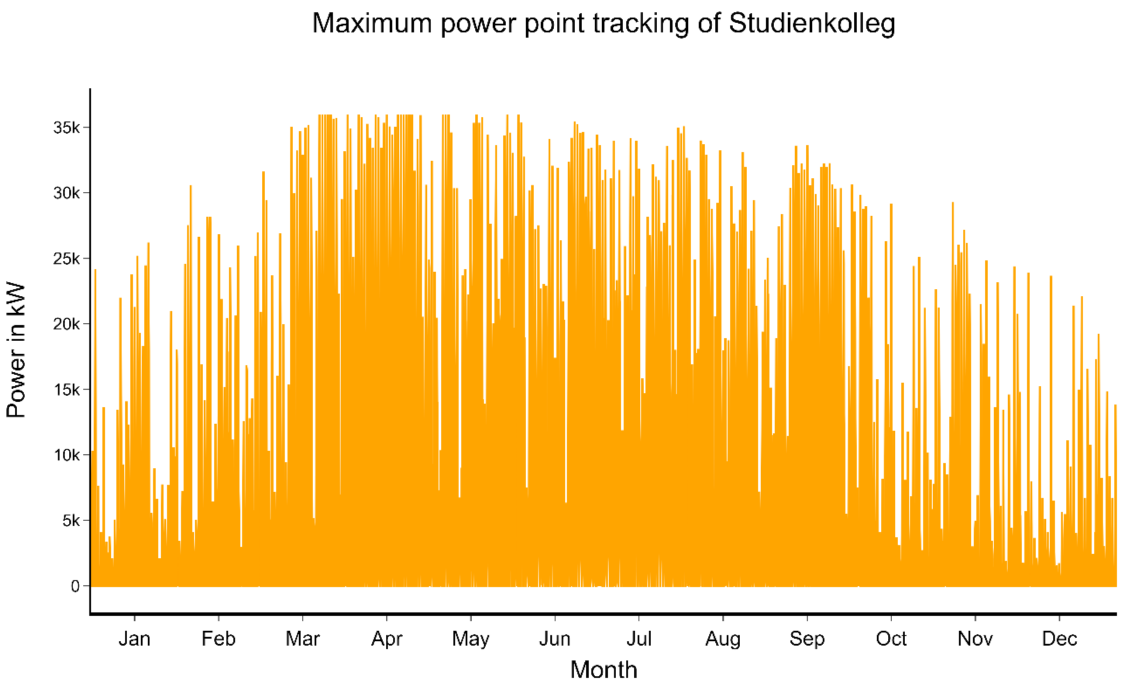

Figure 100 MPP tracking (Studienkolleg)

- Interpretation of results
  From the above energy yield graphs, it can be said that the irradiation plays a major role in generating large amount of electricity as this large amount of is generated from March to September where large amount of sunshine is available. During the periods of low availability of sunshine, the electricity generated is very low.
  From the MPP tracking graphs straight lines can be observed in the months from March to the first week of June. This phenomenon is called inverter clipping, the excess DC electricity will not be converted to AC. This is very common in PV systems as they usually never deliver the rated power so
  It's always better to undersize the inverter from 1.1-1.2 this also makes sense economically.

4.4.3 CAD model of Solar shaded parking

The following is the CAD model of solar shaded car parking, which is designed in CATIA V5. It is designed for the dimensions of the parking lot available opposite to Weinberghof 14. This model depicts the basic layout of the parking roof structure in different angles, as shown in the figure below.

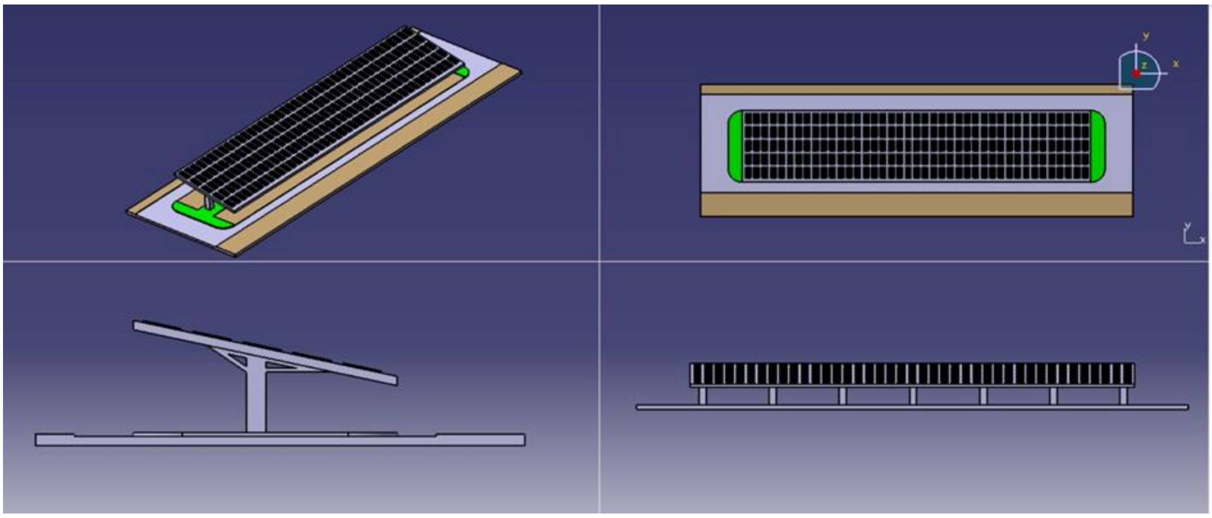

Figure 101 CAD Model of Solar shaded parking roof

4.4.4 Simulation Results

Using a library in python called pvlib, we have simulated the Energy yield of the parking roof top. The following results can be seen in the graphs below. The description of project for parking lot before Weinberghof 14 is as follows we used 350 x Hanwha Q cells 370W modules, area of the roof is 720.15 m2 and the system size is 129.5 kW DC standard test conditions.

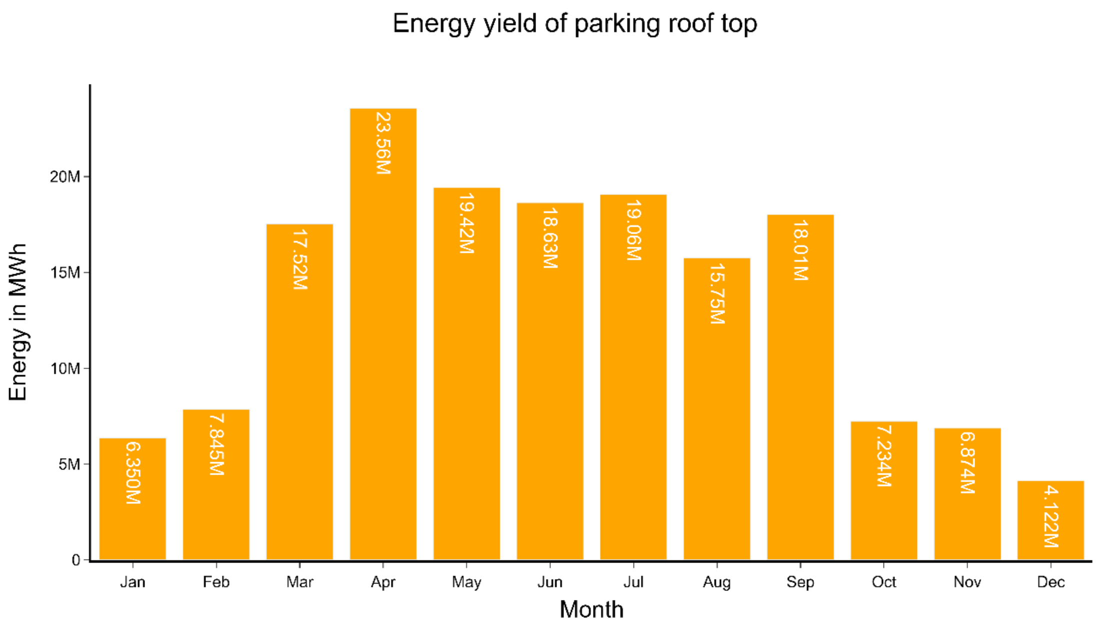

Figure 102 Energy Yield of Parking Rooftop opposite to Weinberghof 14

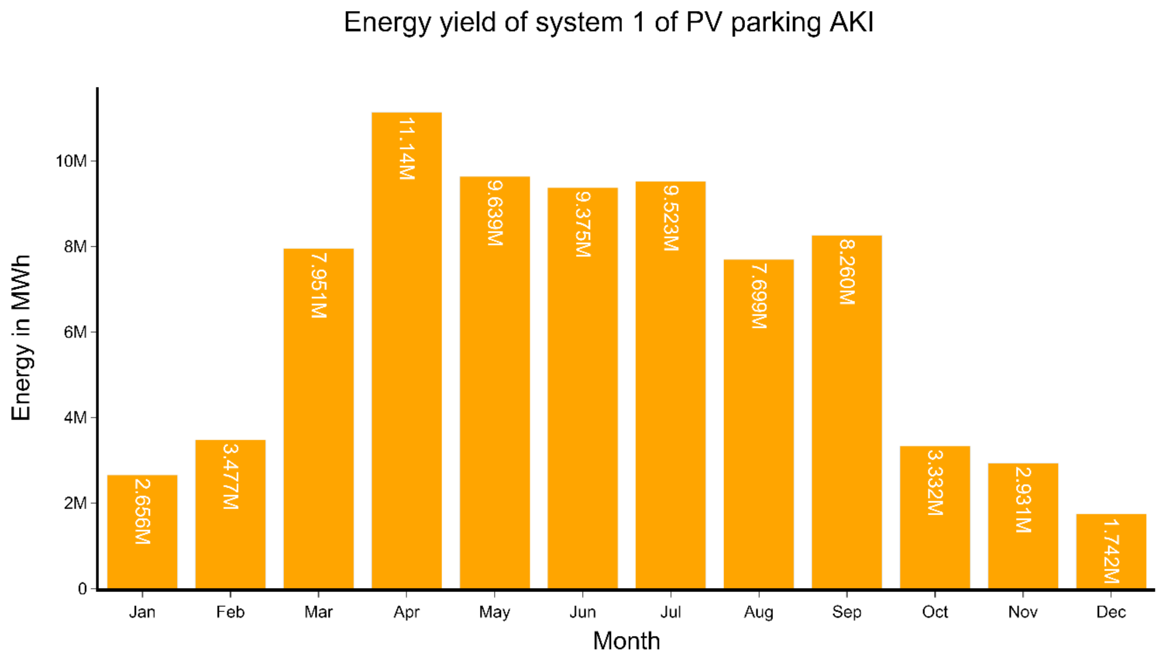

Figure 103 Energy yield of parking behind August-Kramer-Institute (AKI)

The description of project for parking lot behind August-Kramer-Institute is as follows we used 256 x Hanwha Q cells 370W modules, area of the roof is 500.8 m2 and the system size is 94.72 kW DC standard test conditions. In summer months we can see higher yield and in winter months the output depends on the irradiation available.

4.5 Results of Economic Analysis

4.5.1 Demand Analysis

The heat and electricity demand of the university campus is stated in this and the cost of the electricity and heating is calculated. For the implementation of sustainable energy for a particular campus, its demand must be understood, as the consumption pattern and the potential for replacing the usual energy with green energy.

Table 40 Demand and Cost

Building No.	**Electrical energy consumption (KWh/a)**	**Expense of electrical energy (euros)**	**Heating energy consumption (KWh/a)**	**Expense of heating energy (euros)**	**Total expenditure (euros)**
19	78,335.45	32,900.88	25,4760	81,523.2	114,433.08
20	28,138.64	11818.22	50,0280	160,089.6	171,907.82
in.RET (34)	38,180.95	16,035.9	98,560	31539.2	47575.1
Studienkolleg (12)	50,474.54	21,199.3	96,2350	307,952	329,151.3
25	43,279.76	18,177.18	46,7840	149,708.8	167885.98
Parking Roof-top	0	0	0	0	0
Total					830,953.28

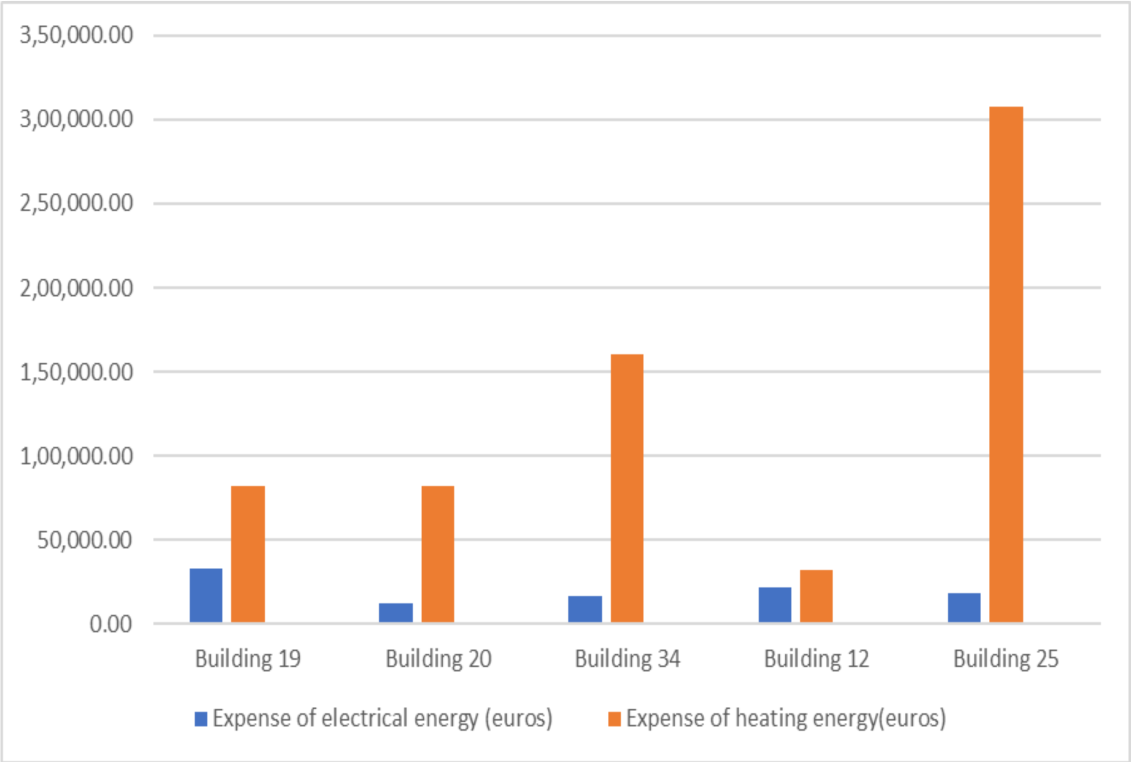

Figure 104 Graph 1 – Energy expense and cost

4.5.2 Cost- Benefit Analysis for Alternatives

This type of analysis is used to determine whether the project is worth spending money and resources and to calculate the monetary value of the project's outcome.

The economic analysis of the Green Renewable Campus in Nordhausen Hochschule was evaluated considering buildings 19, 20, 25, in.RET (34), Studienkolleg (12), and parking roof top. The cost assessment was analyzed in terms of the cost of capital expenditures (CAPEX) and the cost of operating expenditures (OPEX). CAPEX represents the initial cost of a system installation mainly including the cost of solar PV modules, mounting systems, and inverters. However, OPEX includes the operation and maintenance costs of the system on an annual basis. In this analysis, the net present value of the CAPEX was adapted into equivalent annual CAPEX in order to calculate the total annual cost. The equivalent annual CAPEX was calculated using the following formula:

Where NPV is the net present value (CAPEX), r is the discount rate assuming a 10% discount rate, and n is the number of years considering a 20-years project lifetime.

Furthermore, the levelized cost of electricity (LCOE), i.e., the price of electricity, in €/kWh was calculated using the following formula:

Hanwha Q cells 370 W monocrystalline module with 370 Wp nominal capacity was selected for the solar PV modules due to its durability, cost-effectiveness, and considerably high efficiency.
The following tables summaries the economic analysis of solar PV system installation:

Table 41 Energy yield from PV modules

Building	Mounting System	System Size (kW DC)	Inverter power (kW AC)	Annual Energy Yield (MWh/a)
19	TRUE	33.3	35	42.37
20	TRUE	33.3	35	42.37
in.RET (34)	FALSE	39.96	40.05	48.48
Studienkolleg (12)	FALSE	38.48	36	48.38
25	FALSE	66.23	65	86.86
Parking roof top	FALSE	129.5	315	164.37

Table 42 Total cost of the PV modules

Building	PV cost (€)	Mounting cost (€)	Inverter cost (€)	Average O&M cost OPEX (€/a)	Equivalent Annual CAPEX (€/a)	CAPEX+OPEX Annual Cost (€/a)
19	10,256.40	4,995.0	7,000.0	233.1	2,613.64	2,846.74
20	10,256.40	4,995.0	7,000.0	233.1	2,613.64	2,846.74
in.RET (34)	12,307.68	-	8,010.0	279.72	2,386.51	2,666.23
Studienkolleg (12)	11,851.84	-	7,200.0	269.36	2,237.82	2,507.18
25	20,398.84	-	13,000.0	463.61	3,923.02	4,386.63
Parking roof top	39,886.00	-	63,000.0	906.5	12,084.95	12,991.45
Total						28,244.97

Table 43 Cost -Benefit analysis

Building No.	Expense of electrical energy (€/a)	CAPEX+OPEX of using renewable energy (€/a)	Revenue generated by using Renewable energy(€/a)
19	32,900.88	2,846.74	17795.4
20	11,818.22	2,846.74	17795.4
in.RET (34)	16,035.9	2,666.23	20361.6
Studienkolleg (12)	21,199.3	2,507.18	20319.6
25	18,177.18	4,386.63	36481.2
Parking Roof-top	0	12,991.45	69035.4
Total	100131.48	28244.97	181788.6

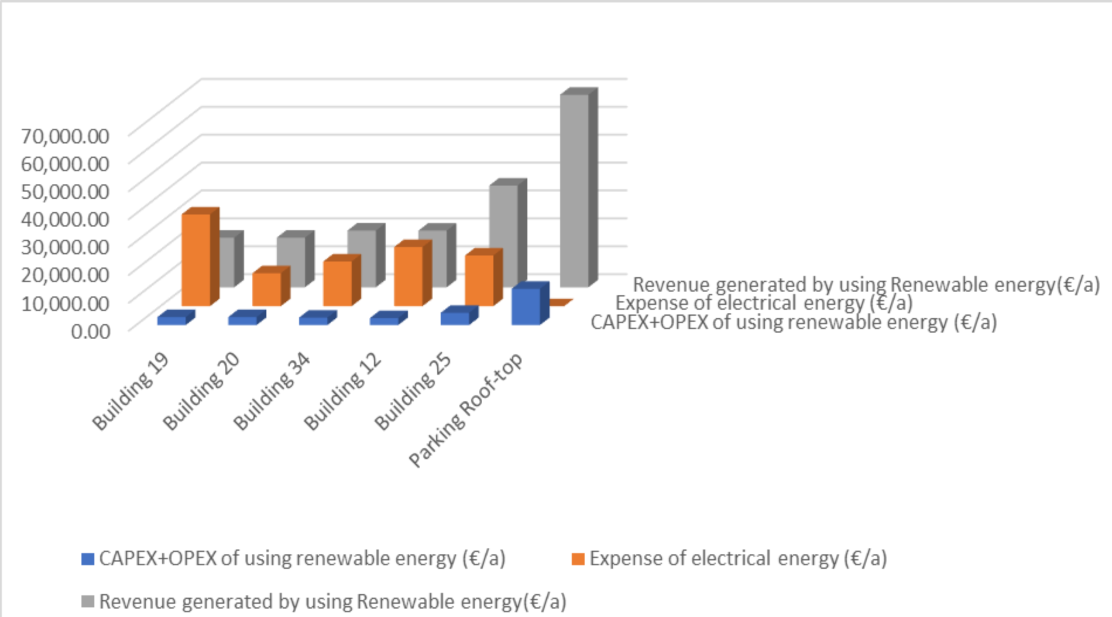

Figure 105 Graph – Cost- Benefit analysis

The economic analysis of the Green Renewable Campus in Nordhausen Hochschule was evaluated considering buildings 19, 20, 25, in.RET (34), Studienkolleg (12), and parking rooftop. The cost assessment was analyzed in terms of the cost of capital expenditures (CAPEX) and operating expenditures (OPEX). CAPEX represents the initial cost of a system installation mainly including the cost of solar PV modules, mounting systems, and inverters. However, OPEX includes the operation and maintenance costs of the system on an annual basis. In this analysis, the net present value of the CAPEX was adapted into equivalent annual CAPEX in order to calculate the total annual cost. The equivalent annual CAPEX was calculated using the following formula:

Where NPV is the net present value (CAPEX), r is the discount rate assuming a 10% discount rate, and n is the number of years considering a 20-years project lifetime. Furthermore, the levelized cost of electricity (LCOE), i.e., the price of electricity, in €/kWh was calculated using the following formula: Hanwha Q cells 370 W monocrystalline module with 370 Wp nominal capacity was selected for the solar PV modules due to its durability, cost-effectiveness, and considerably high efficiency.

The following tables summarize the economic analysis of solar PV system installation:

Table 44 Economic analysis of solar PV system install

Building	Mounting System	System Size (kW DC)	Inverter power (kW AC)	Annual Energy Yield (MWh/a)
19	TRUE	33.3	35	42.37
20	TRUE	33.3	35	42.37
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25	FALSE	66.23	65	86.86
Parking roof top	FALSE	129.5	315	164.37

Table 45 Economic analysis of solar PV system installation

Building	PV cost (€)	Mounting cost (€)	Inverter cost (€)	Average O&M cost OPEX (€/a)	Equivalent Annual CAPEX (€/a)	CAPEX+OPEX Annual Cost (€/a)
19	10,256.40	4,995.0	7,000.0	233.1	2,613.64	2,846.74
20	10,256.40	4,995.0	7,000.0	233.1	2,613.64	2,846.74
in.RET (34)	12,307.68	-	8,010.0	279.72	2,386.51	2,666.23
Studienkolleg (12)	11,851.84	-	7,200.0	269.36	2,237.82	2,507.18
25	20,398.84	-	13,000.0	463.61	3,923.02	4,386.63
Parking roof top	39,886.00	-	63,000.0	906.5	12,084.95	12,991.45
Total						28,244.97

4.5.3 Results of Cost- Benefit Analysis

The total cost of installation and operation was compared with the average output by the PV modules and it was found that these buildings generated more power than the required amount and this extra energy can be used to provide power to other buildings or can be connected to the main supply line of the grid. This also results in a significantly decreased payback period.

Payback Period:
This is defined as the time period required to recover the initial capital investment. The system described here generates a net profit of 53412 € and it will take 50 months to recover the total investment.

4.5.4 Financial Constraints

- Financial constraints are inevitable factors to be considered while implementing sustainable energy. There are also various expenses and factors associated with it.
- The most obvious costs are the capital costs and installation. Wind turbines, solar panels, and energy-efficient buildings, often require significant principal investments.
- Less financial support: Comparatively smaller institutions might face financial challenges in implementing green energy project-.
- Uncertainty of energy prices: Fluctuations in the prices of fossil fuels might give difficult time deciding whether to go for a sustainable solution or not.
- Storage challenges: During peak hours, the energy produced must be stored and that might lead to storage problems, and energy storage is quite expensive.
- The amount of government support can play a crucial role in the financial aspect.

While such challenges are there, green energy and its use are getting economically viable, with production costs on a decline and newer technologies being developed.

4.4.5 Valuation of Project Benefits

- Fuel Cost Savings: The installed system can generate more energy than the required amount. This results in savings of around a hundred thousand euros annually.

- Unquantified Benefits: These are the benefits for which no values can be assigned and are included in the analysis for a conservative approach. Some of the unquantified benefits can include:

- Improved environmental impact: By reducing their carbon footprint, universities can help mitigate the effects of climate change and demonstrate leadership in sustainability.

- Enhanced reputation: Universities that embrace green energy can improve their reputation among students, faculty, staff, and the wider community.

- Inspiration and education: By implementing green energy systems, universities can provide a real-world example of sustainable practices and encourage students to pursue careers in clean energy and sustainability.
- Increased innovation: By investing in green energy, universities can spur innovation in clean energy technologies and position themselves as leaders in sustainability.

4.6 Results from Transport Concept

4.6.1 Travel Buddies for Car Pooling

All over Europe, the transport industry remains as a main contributor to the Greenhouse gas emissions. The majority of transport emissions come from the road, which in 2021 contributed 72% of total greenhouse gas emissions from domestic and foreign travel in the EU [56]. In recent times, the EU and especially Germany has made tremendous strides towards reducing the emissions. Considering the topic of our research 'Green Campus at HS Nordhausen, the analysis of emissions at HSN and the implementation of possible solutions is of prior importance. The point of analysis is already mentioned in the chapter 3 and now we are going to deal with some solutions which can help to bring down the emission levels to some extent.

Travel buddies for Carpooling is the very first idea which comes into our mind while looking for a feasible solution. Our University, HS Nordhausen already has a well-established network and mechanism for helping the students who are new to the town of Nordhausen through a 'Buddy Program'. The program provides a fresher to the town (if he/she need)with a buddy who knows the area in detail and the buddy helps them in their initial paper works. The idea we propose is to use the same work force behind this buddy program platform to connect the people who travel in same direction. When several people share a vehicle to travel together, the term "carpooling" is used. The car used for carpooling is owned by a member of the group [57]. First of all, there are a lot of people who travel above 15 km a day to reach the university from nearby towns or cities. Most probably they are traveling to the university on a daily basis i.e., 5 days a week or on the days they have lecture hours. An initiative can be taken at any levels, within the course group or at the university level to connect between people who come from the same cities and who are traveling in the same directions.

If the initiative is to be taken at university level, then the procedure similar to the buddy program can be applied to here also. The one who wish to join this program can mail the university on the specific Email address and can mention specifically which direction he/she is going to travel regularly, where they can wait for pickup(nearby bus stop or train station) and the most important thing whether they have a car or not. The next procedure is to allocate the person who is not having a car to the one who has a car and is on the same route of travel. In the case of cars, most of the time a minimum of 4 to 5 people can travel very comfortably. The idea we suggest is only to connect the people traveling along the same route, the rest of the things like how many can travel at a time, how much money they should spent etc. should be taken care by the specific individuals. The initiative of organizing can be done by students of the same course but the number of persons going in the same direction will be minimal. That's why we suggest to allocate travel buddies at the university level, so that the ratio success and benefit will be more.

Figure 106 Carpooling [32]

4.6.2 Moodle as A Platform for Connect for Travel

Moodle is a word familiar to the students and staff of HS Nordhausen and we are using it for our educational purposes. It is utilized for blended learning, distant learning, flipped classrooms and other online learning initiatives [58]. We have been using it for our studies, where we attend online lectures, regular examination, assessment, get access to notes and details about classes. It remains as a medium for communication between the professors and students. Each course has a separate page with a moderator in it, most probably only the professor who is conducting the lecture. The moderator is responsible for editing and modifying the course profile and the details included in it. We can use the functions of Moodle to make it suitable for our idea of connecting people to travel together.

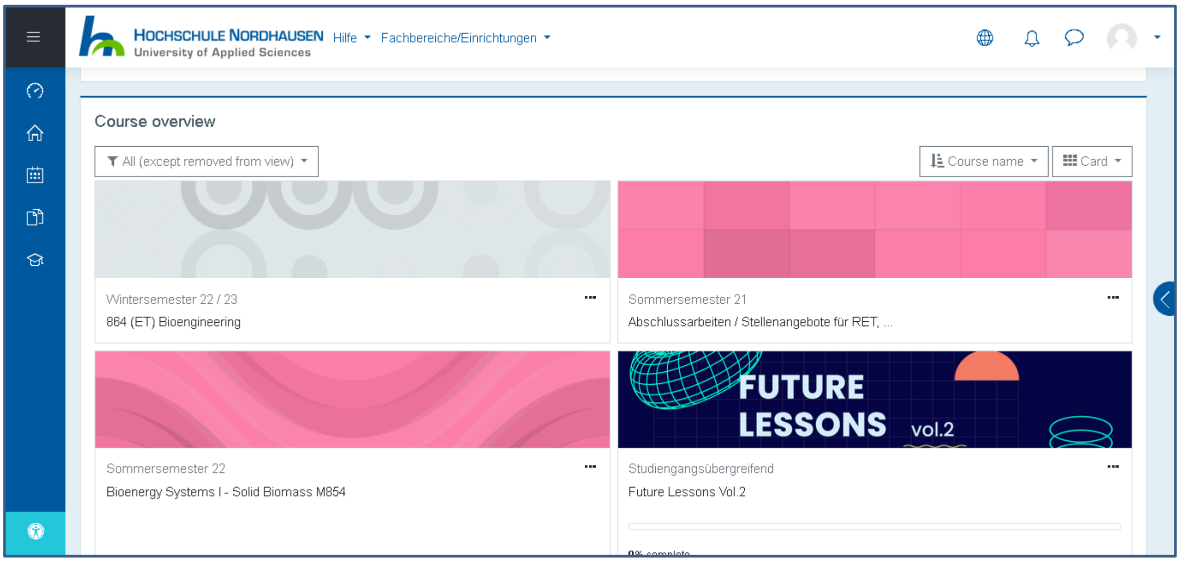

Figure 107 Figure Moodle Layout [33]

The feature called Forum can be used for our purpose, as there is a possibility to create a discussion in the Moodle course. Our idea is to create a course in Moodle for connecting people for travel which can be moderated by anyone from the university and giving the one who has enrolled in the course the permission to comment their travel details in the discussion section. The individuals enrolled in this course will get a notification after each update and those who are interested in that specific travel can message the respective person who has posted their details of travel. This remains as an easy way of connecting with people and it doesn't disturb those who are not interested in the content.

5. Future Scope

5. Future scope for the potential of renewable resources on the University campus.

5.1 Wind Energy Potential

Germany is one of the windiest countries in Europe. It is a meteorological advantage that is enabled Germany to deploy around 1500 huge wind turbines across the country with a generating capacity of almost 8.1 GW providing up to 5% of Germany's Electricity [46].

Wind power is one of the fastest-growing renewable energy resources in many parts of the world. The Laws of physics and fluid dynamics, which include the fact that wind speeds are generally faster at higher altitudes and that doubling the wind speed increases its energy by Eight times, means that wind turbines are growing even larger in order to capture that energy and increase their efficiency. Massive installations like this also, quite rightly require extensive planning and regulatory permissions before they can proceed, and they typically require some kind of financial backing and guarantees from national governments to prevent them from becoming very costly installations. For all these reasons wind generation today remains almost exclusively the responsibility of larger centralized states and national power producers and grids.

A. Approach for harvesting Wind Power:

Furthermore, to determine the wind potential of a specific location through prospecting and feasibility study. Pre-feasibility studies are preliminary research projects designed to identify, evaluate, and choose the most promising scenarios before installation. The next step is to use a meteorological method to collect wind resource data for a year across all seasons. As a result, it is critical to know the wind speeds and directions throughout the year in order to accurately predict the AEP (annual energy production). (Wind Flow Simulation). Higher AEP results in lower wind energy electricity costs per kWh. Local effects such as orography, roughness factor, and Obstacles play an important role while prospecting the site.

B. The Position of our University

Our university is situated in a densely populated neighborhood with a lot of buildings. Local effects on installations and power generation, such as a roughness factor, orography, and obstacles. Half of the university's geological plan has orography means elevated land, which is also a local effect that must be considered. There are many buildings around the university and inside the campus, so another local effect considers buildings as obstacles for wind that must pass through wind turbines when calculating potential wind energy.

However, there is a new wind technology by Aeromine Technologies for rooftops that requires a flat roof of the building and wind must blow from a single direction throughout the year to produce wind power, and our university building 19 & 20 are ideally situated. As a result, this new wind technology can be used as a rooftop. These buildings are situated in such a way that mostly the wind blows at an average of 218.27 degrees, which means south-west direction if the north direction is taken as 0 degrees throughout the year from wind resource data from the NASA Power data access viewer and Python tool [47]. The average mean wind speed calculated by python is 3.63 m/s considering all directions throughout the whole year. These results are calculated with two methods below.

5.2 Further Suggestion for Travel

The buses which connect the university with other locations remain as one of the best transport solutions. The analysis conducted by us clearly depicts how much the buses are contributing to the greenhouse gas emissions, since most of them are still running in fossil fuels and only a very few runs with electric power in Nordhausen. It is not possible to change the buses which are running on conventional fuels all of a sudden and replace them with electric or CNG buses because the cost associated with buying buses, their charging or refueling stations and maintenance are exceptionally high. Moreover, it is not a matter which university can easily interfere and make changes. It relies on the hand of the city administration and also along with the transport association in the town. Therefore, the one solution the university can put forward is to provide free electric charging for the buses. When the plans proposed by potential determination are successfully installed, the university can contribute electricity for charging the buses, which will be a very big help for the local administration and transport association. For settling up charging stations there are additional costs needed for the transport company but as per the plans proposed we are incorporating charging stations along with solar shaded parking. As a result, the financial burden on the transport association can be reduced and the university also will not cost more.

The other idea we can put forward is to motivate the students and staff to use Bicycles and E-Bikes and Electric scooters. As per the results of the survey done by us, during summer a lot of people use bicycles or electric scooters compared to that of winter, in spite of that the number is very low when taking the overall count of people in Hochschule. The usage of bicycle or electric scooters needs to be improved and this can be done with the help of the university. For example, electric scooters are costly as compared to normal bicycles and in addition they need to be electrically charged before use. In the current scenario of increase in the cost of electricity, students themselves feel reluctant to buy electric scooters as their cost of living also increases along with it. The suggestion is to provide free charging or charging at a low cost to the students by utilizing the charging spots associated with charging spots in solar shaded parking. The access to charging equipment and the amount for the usage can be debited using the Thoska in the student's hand. Students who are using the facility of charging should recharge their cards separately for this purpose and can use it till they are enrolled in the university.

6. Conclusion

6. Conclusion

The Project GreenCampus is an important initiative taken by the university to promote sustainability and reduce the environmental impact through implementation of various renewable energy sources for energy demand, various energy saving options, etc. along with their feasibility for the University as well as the stakeholders. With the help of the data acquired during the entire project duration, from researching about the methods applied by sustainable universities, to determining and calculating the feasibility aspects, this project has created a great impact on the students, faculties and administrative staff of the university.

An overview of the works done by other sustainable universities suggested of implementing concepts like energy efficiency, renewable energy, sustainable transportation and waste reduction. To work on these concepts, measures like recycling of various materials, using materials made of recycled materials, promoting E-mobility solutions, installing PV modules and small-scale wind turbines for electricity generation along with solar thermal systems and biomass boilers for space heating and DHW heating applications were identified.

To implement the above solutions, firstly the energy demand for the university has been determined where various factors like different usage behaviors in different buildings with respect to the equipment in the building, working hours, area of the building, application of the building etc. were considered. Data acquisition and collection was done for all the buildings of the University to find out the mentioned factors and facilitate the data analysis and calculations for the other groups. This collected data was then taken into account and processed to determine the heat energy supply for entire campus of Hochschule Nordhausen. It involves determining the amount of heat required to maintain a comfortable indoor environment, considering various factors such as building insulation, internal loads, and outdoor weather conditions. Accurate heat demand calculation is essential for designing and operating efficient heating systems, as well as for reducing energy consumption and reducing greenhouse gas emissions.

Heat energy demand for the Hochschule Nordhausen campus is 2569.74 MWh/a. Here the campus is divided into two parts according to the geographical way North Campus and South Campus for ease of calculation. There are many different types of buildings like residential, commercial, and industrial having different demands. Here, the heat energy demand and consumption along with their load profile and load duration curve for one building of each type were calculated to demonstrate the usage behavior of each type of building. The demands in these buildings are the Domestic water heating (DWH) systems and Space heating systems. Right now, these demands are covered by certain outside sources. For the aim of the project, making the Hochschule Nordhausen campus self-sustain, these calculative results will serve as a foundation for the future integration of heat supply by renewable energy sources.

The electrical energy demand for the Hochschule Nordhausen campus is calculated to 1196.55 MWh/a after considering all the factors. The methodology adopted to calculate the electric demand is similar to that of methodology adopted to calculate the heat energy demand. The difference being the factors considered to determine the electric load and electric consumption like identifying the critical load, nominal load, surges and working hours of the equipments of the University.

The analysis from previous data and the calculations shows that the Winter season (November to February) have the highest heat and electricity consumption while the summer season (mid-April to mid-August) has the least consumption which also includes the two semester breaks. The transition period i.e., the Spring and Autumn seasons (March to mid-April and mid-August to November), have approximately similar usage where the consumption gradually decreases in Spring and vice versa in Autumn. To satisfy these energy demands, system modeling on various alternatives for conventional energy supply sources was done.

The various alternatives considered to satisfy the energy demand majorly includes roof mounted PV systems along with stationary roof top wind power technology “Aeromine” for the electrical energy demand. Geothermal energy and solar thermal systems have been proposed to satisfy the space heating and DHW applications. The most relevant and reliable system that could be installed within the University campus is determined to be the photovoltaic system (PV System) according to the available area available on the building rooftops. Also, the concept of solar shaded parking has been proposed to extract more potential from the available area of the university other than the roof tops. The solar shaded parking can be installed as per the optimum PV requirements and provides protection to vehicles parked in two selected parking areas, the first area to be parking lot in front of Weinberghof 14 and other besides AKI (building 28). The total photovoltaic potential is calculated to be 565.03 MWh/a where the share of rooftop PV from buildings is 277.38 MWh/a and from solar shaded parking is 287.65 MWh/a.

The roof top wind power technology was not considered in current situation due to the fact that though this new technology has higher yield as compared to PV system, the costs of PV systems are cheaper due to advancements of this system. Moreover, the availability of the new wind power technology is limited in Europe and specifically in Germany. The Geothermal potential was ruled out of consideration due to the main factor being University area laying under unfavorable area according to the Thuringian Water Act (ThürWG) for the DHW and space heating applications. The roof top systems are dedicated for PV systems and therefore the Solar thermal energy production to satisfy the heat demand is not being considered. The focus has given firstly to satisfy the electric energy demand. However, only 47.22% of electrical energy demand could be satisfied by the proposed model of the PV system.

The economic perspective of the project determines the expenditure to be 830,953.28 €/a for the buildings 19, 20, in.RET 34, Studienkolleg 12, 25 and parking roof top (near Weinberghof 14) of the University campus which are the major PV energy producing sites. After the installation of the PV systems, the revenue generated by this system is calculated to be 181,788.6 €/a which is approximately 22% of the capital expenditure for energy of these sites. The site generating major energy yield and capital is the Solar shaded parking and hence being the best solution for the modeling done.

A schematic Life cycle flow process has been built to determine the sustainability of the proposed systems to be installed in the University. This is important to determine the environmental impact of the derived system during its manufacturing as well as its use phase to its end-of-life phase along with the decommissioning and recycling of the materials used for the system.

The further measures to move a step forward towards sustainability is by reducing the resource usage, weather it is over usage of electricity, heat, water or fossil fuels in transportation. Energy savings needs to be integral behavior in the society. This could be adopted by using Moodle as a platform for carpooling for the University staff and the students along with providing free EV charging station for the vehicles coming in the university, indirectly promoting the use of EVs in the society in the transportation sector. Regular energy audits need to be carried out to track the energy usage in the University to utilize the resources wisely and reduce the unnecessary usages whenever possible. Energy efficient devices like automatic (motion sensor) lights, smart windows and others like energy storage systems, heat controlling temperature sensors could be employed in the classrooms, student apartments and the Campus area to minimize the energy usage.

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Miscellaneous	
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Students With Matriculation Number -

1. Abhishek Sharma	(44134)
2. Romit Bhavsar	(44098)
3. Henry Esomonye	(43806)
4. Gaurang Chhapia	(44122)
5. Dala Jaswanth	(44127)
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29. Elvis Obamwonyi	(44532)
30. Meenal Kshirsagar	(44128)
31. Rahul Patil	(44175)
32. Samarth Kota	(44093)
33. Sandip Bhatta	(44374)
34. Sharath Thummalapally	(44207)
35. Sreejith Surendran Nair	(44151)
36. Sai Teja Nakka	(44173)
37. Karan Rathod	(44107)
38. Smith Falcao	(44131)
39. Tarek Abdelrasoul	(44529)
40. FONGANG MBA Jordan	(80195)

41. Kuma Eriksso (44097)
42.Arnish Thesiya (44193)
43.Oguka Amarachukwu (44035)
44.Ahmed Abdelall (44528)
45.Tarek Gad (44541)

Number of Groups and Members-

- MEDIA PREPARATION

1. Tarek Abdelrasoul,
2. Neel Bhavsar, `
3. Kuma Erkisso,
4. Smith Falcao,
5. Abhishek Khairnar,
6. Meenal Kshirsagar,
7. Salman Pasha Mohammed,
8. Jimesh Patel,
9. Karan Patel,
10. Parth Vachhani

- HEAT ENERGY SUPPLY

1. Tarek Abdelrasoul,
2. Arsalein Belgasmi,
3. Jordan Fongang MBA,
4. Sharath Chandra Kandala,
5. Salman Pasha Mohammed,
6. Elvis Obamwonyi,
7. Jimesh Patel,
8. Nisarg Patel,
9. Rahul Patil

- ELECTRIC ENERGY SUPPLY

1. Romit Bhavsar,
2. Pratik Fundkar,
3. Gaurang Chhapia,
4. Sai Teja Nakka,
5. Rahul Eshwar Patil,
6. Sharath Thummalapally,
7. Jemin Vora

- TRANSPORT CONCEPT

1. Neel Bhavsar,
2. Romit Bhavsar,
3. Jaswanth Dala,
4. Jiteshkumar Prasad,
5. Karan Rathod,
6. Arjun Sasi,
7. Sreejith Surendran Nair
8. Arnish Thesiya,
9. Jemin Vora

- ECONOMIC ANALYSIS

1. Neel Bhavsar,
2. Dania Kabakebji,
3. Samarth Kota,
4. Jimesh Patel,
5. Karan Patel

- POTENTIAL DETERMINATION

1. Jaswanth Dala,
2. Kuma Erkisso,
3. Gaurang Chhapia,
4. Gnaneshwar Reddy Kolan,
5. Salman Pasha Mohammed,
6. Nisarg Patel,
7. Dharm Patel,
8. Arjun Sasi,
9. Abhishek Sharma,
10. Sreejith Surendran Nair

- SUSTAINABILITY ANALYSIS

1. Henry Ifeanyichukwu Esomonye,
2. Dania Kabakebji,
3. Elvis Obamwonyi,
4. Amarachukwu Oguka,
5. Rahul Patil

- DATA ACQUISITION

1. Arsalein Belgasmi,
2. Henry Ifeanyichukwu Esomonye,
3. Sharath Chandra Kandala,
4. Elvis Obamwonyi,
5. Nayan Pansuriya,
6. Dharm Patel,
7. Kandarp Sanjaybhai Patel,
8. Karan Bharatsinh Rathod,
9. Arnish Thesiya,
10. Parth Vachhani

- SAVINGS OPTIONS

1. Ahmed Abdelall,
2. Sandip Bhatta,
3. Nishant Bhilare,
4. Tarek Hamdy Gad,
5. Anuja Ramakant Kahane,
6. Gnaneshwar Reddy Kolan,
7. Omar Masoud,
8. Farag Mokhtar,
9. Abhishek Satish Patil,
10. Sharath Thummalapally

- DOCUMENTATION

1. Pratik Fundkar,
2. Jay Anup Jakkal,
3. Samarth Kota,
4. Meenal Kshirsagar,
5. Amarachukwu Oguka,
6. Kandarp Sanjaybhai Patel,
7. Henry Ifeanyichukwu Esomonye,
8. Jordan Fongang Mba,