Increasing community acceptance of photovoltaic developments

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STUDENT REPORT

Abstract

This research concerns the local planning process of big-scale photovoltaic power plants. It answers the main research question "How can planners and developers mitigate the risk of halting or delaying PV solar farm projects by increasing community acceptance?" using the theory of Choice Awareness while analyzing actors by using Stakeholder Analysis. This qualitative and quantitative master project examines the multifaced impact of photovoltaic (PV) modules, considering technological, economic, psychological, and sociological factors. The project reveals that community involvement is frequently insufficient and highlights a variety of factors influencing the acceptance and implementation of PV solar farms. It is clear from thorough document analysis and interviews that public dialogue and transparency are absent, which has raised concerns in the community regarding the returns on these investments. Ultimately, this research offers new approaches for private developers and planners to improve community acceptance and expedite the installation of solar systems.

Pages: 60

Appendices: 2

Supervisor: Kristian Borch

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Preface

This master’s thesis is written in the period 1.02-5.06 2024. In the fourth semester of the master’s degree in Urban Planning and Management at Aalborg University (AAU). The report is based on problem-based learning.

Embarking on this master's project has been a pivotal experience in my academic and professional development. Driven by a deep-seated passion for a sustainable world transition, this research delves into sustainable planning—a field that has fascinated me throughout my academic career.

This project would not have been possible without the support and guidance of numerous individuals. I would like to extend my heartfelt gratitude to my supervisor, Kristian Borch, whose extensive knowledge, patience, and unwavering support have been instrumental in shaping the direction and quality of this study. I also express my deep appreciation to Andreea Andrei for her steadfast support throughout this journey.

Finally, I express my deepest appreciation to my family and friends for their unwavering support and belief in my abilities, which have been a constant source of motivation.

Referencing

For referencing, the Harvard referencing style was applied (Author, Year of publication). All the references are included in the bibliography.

If the reference is not given the table, graph, or image was done by myself.

1. Introduction

From 2000 to 2010, global electricity demand doubled every two years, followed by a slightly slower rate of doubling every three years. This year, global electricity demand increased by 627 TWh, an amount comparable to the entire electricity demand of Canada (Wiatros-Motyka et al., 2024). Concurrently, global CO2 emissions reached 14,153 million tons. In 2023, fossil fuels like coal and gas accounted for 61% of global electricity production (Wiatros-Motyka et al., 2024).

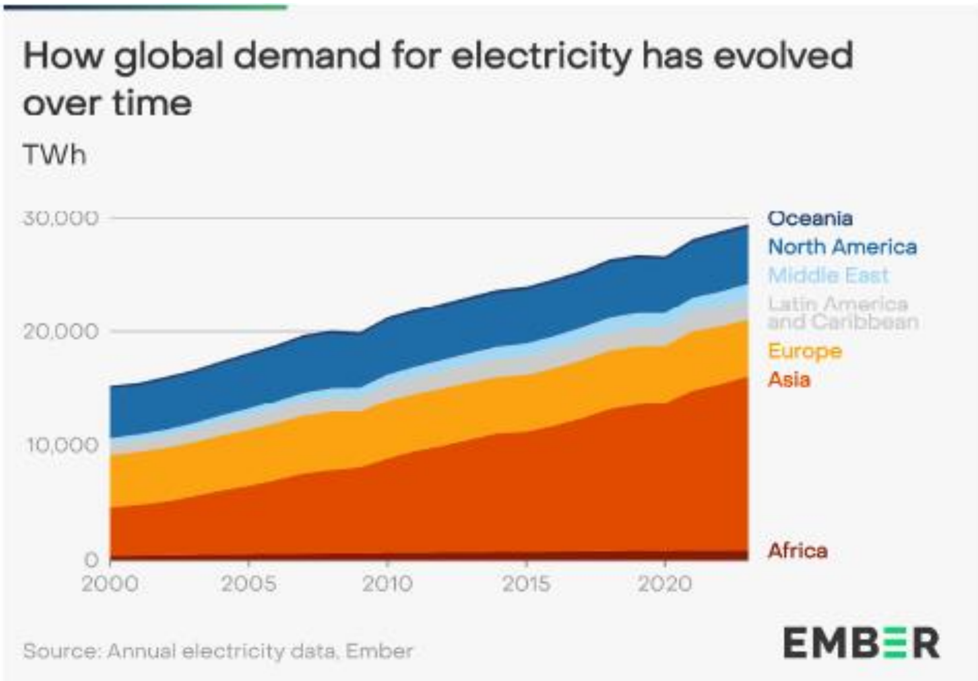

Figure 1- How global demand for electricity has evolved over time (Wiatros-Motyka et al., 2024)

In terms of energy demand, Asia takes the lead, followed by Europe and Latin America. Interestingly, despite being the fourth-largest CO2 emitter globally at 657 million tons, the European Union has the smallest proportion of fossil fuels in its electricity mix among the top four emitters. However, per capita power demand within the EU is nearly 66% higher than the global average. To achieve the International Energy Agency's Net Zero Emissions (NZE) scenario from 2023 to 2030, energy capacity needs to almost double every four years (U.S Energy Information Administration, 2023; Wiatros-Motyka et al., 2024).

1.1.1 Energy consumption

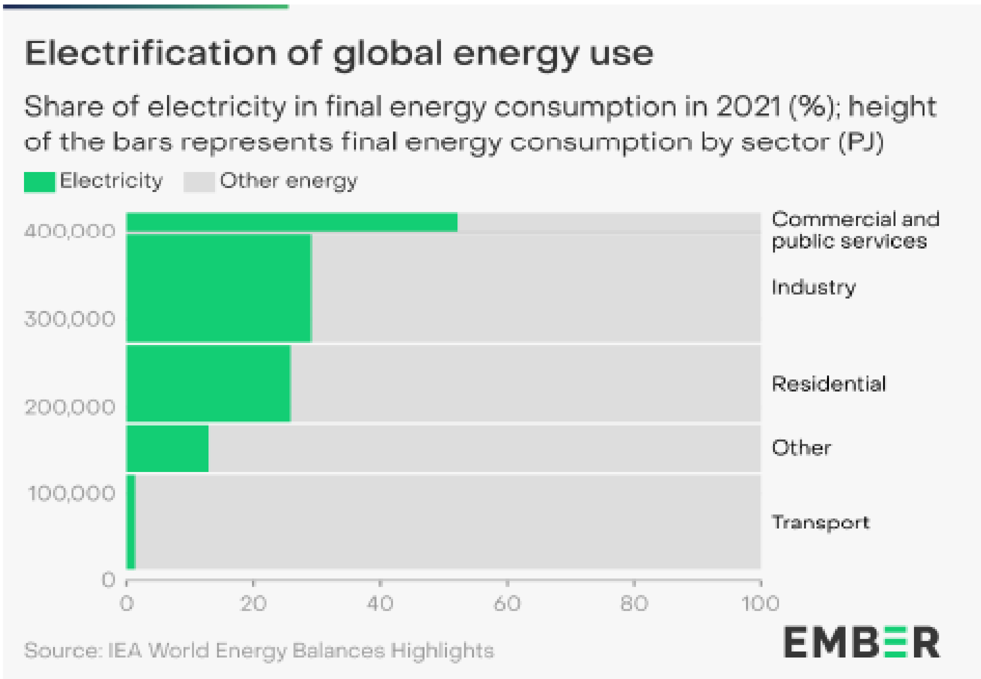

Figure 2-Electrification of global energy use (Wiatros-Motyka et al., 2024)

Many analyses indicate that the power sector is responsible for over a third of energy-related CO2 emissions. To address this, a shift to renewable energy sources is essential. At the UN's COP28 climate conference, nations agreed on a target to generate 60% of electricity from renewable sources by 2030 (Wiatros-Motyka et al., 2024,U.S Energy Information Administration, 2023).

"Forty percent of the energy generated in the world is consumed in buildings"(Lee et al., 2020)

As cited by the authors of the article titled "The Development of Transparent Photovoltaics," almost half of the consumed energy is attributed to buildings. Additionally, the world population is growing by almost 1% every year (Lutz et al., 2013). It can be inferred that with such rapid population growth, the demand for energy is also on the rise (Hernández-Callejo et al., 2019). Society's increasing need for electrical power, coupled with concerns over environmental degradation, underscores the necessity for renewable energy sources. In light of biodiversity loss, reliance on fossil fuels for electricity generation is no longer viable. Given the technology available today, nations should prioritize the development of renewable energy sources (Wiatros-Motyka et al., 2024).

Russia's invasion of Ukraine, coupled with supply cuts, has resulted in soaring oil prices, highlighting the uncertainty and risks associated with reliance on fossil fuels. Fortunately, the decreasing costs of renewable energy sources are paving the way for cheaper energy in the future. A swift transition to renewable energy offers numerous benefits, including improved air quality, reduced dependence on oil, and the creation of employment opportunities (Wiatros-Motyka et al., 2024). The perspective shared by the author of "A Review of Photovoltaic Systems: Design, Operation, and Maintenance" on energy consumption is compelling. As stated:

"Energy consumption determines how much and how severely we can affect our environment, and how damaging or healing our interactions with it are. Its role is vital for our life and for our economy." (Hernández-Callejo et al., 2019)

This underscores the vital role energy plays in both our lives and our economy. Managing energy production effectively and planning its distribution are paramount considerations. It's essential to enhance our focus on energy planning and raise awareness about energy consumption. This entails facilitating easy access to data and knowledge while promoting the adoption of sustainable solutions (Hernández-Callejo et al., 2019).

1.1.2 Renewable energy

Currently, renewable energy sources generate 30% of global electricity, with solar power being the leading contributor. Solar power has been the fastest-growing renewable energy source for 19 consecutive years. In 2023, photovoltaics provided twice as much new energy as coal. As highlighted, solar energy represents a revolutionary force that can help achieve energy goals and set the electricity sector on a path to meet climate targets, as reported by Ember (Wiatros-Motyka et al., 2024).

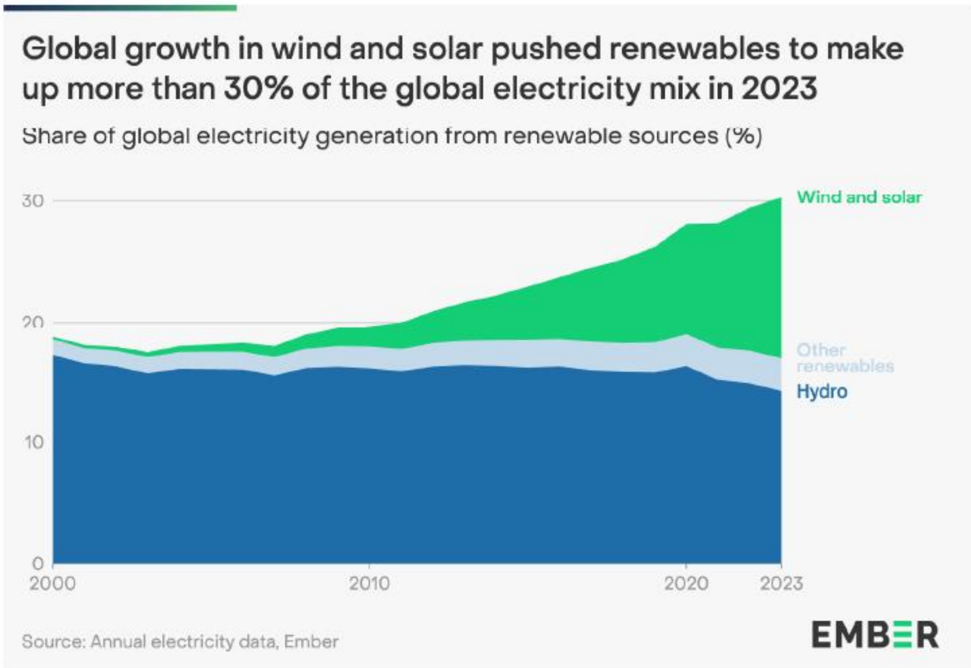

Figure 3- Global growth in wind and solar pushed renewables to make up more than 30% of the global electricity mix in 2023 (Wiatros-Motyka et al., 2024)

Photovoltaics provides a clean power generation method that meets local energy demand quickly and efficiently. According to the International Energy Agency, solar energy is now the cheapest energy source in history. This attractiveness stems from significant cost declines, more supportive environmental policies, improved technology efficiency, and increased manufacturing capacity (U.S Energy Information Administration, 2023; Wiatros-Motyka et al., 2024). However, solar power generation is not constant, as it depends on sunlight availability. Sometimes there is a surplus of generated energy, and other times demand exceeds supply. Countries with abundant sunshine, such as Spain and Australia, can generate almost 20% of their power from solar energy. Nevertheless, nations with less favorable insolation, like Germany and the Netherlands, continue to invest in solar power, underscoring the potential of this technology regardless of natural conditions (Wiatros-Motyka et al., 2024).

This master project seeks to investigate solar panels as a renewable energy source, in the aspect of generating green energy profit to society. As was mentioned in the book called “Photovoltaics: System Design and Practice”, photovoltaics (PV) is incredibly clean and environmentally friendly, it doesn’t emit any hazardous gases or produce any sound. Moreover, it doesn’t engender any toxic waste. So why only 5,5% of the world's energy mix is provided by photovoltaics (Wiatros-Motyka et al., 2024)?

1.1.3 Issue

Pv farms have an influence on the landscape of the area and can lead to social acceptance issues (Vuichard et al., 2021). It can be found that a high influence on PV farm acceptance has a socio-political aspect. Without socio-political acceptance, there is a lack of successful deployment of renewable energy technology. It is said that to have a greater level of acceptance among the citizens, developers, and the local government should establish a clear understanding of the incoming project, its benefits, and possible negative effects (Vuichard et al., 2021). Moreover, when the citizens have clarity about the project and feel the so-called distributional justice (Wüstenhagen et al., 2007), which means a fair decision process and fair distribution of costs and benefits, they are more likely to accept the investment. It is suggested that a great influence on solar power plant acceptance is the involvement of the public. Citizens consultations, public gatherings, and social meetings lead to a smaller resistance among the people living near the new investment. Moreover, political attitudes have a significant impact on the acceptance of renewable technology in the region (Vuichard et al., 2021).

1.1 Multi-purpose PVs

If there is significant resistance to large-scale photovoltaic farms, innovative solutions are needed to develop renewable energy sources without public opposition. One approach is to combine photovoltaics with agricultural activities, creating multipurpose benefits from large solar investments. The Polish Photovoltaic Association conducted research on integrating solar panels with land harvesting. They explored various methods to combine agriculture with green energy production. One idea involves installing photovoltaic modules above crops, which have been proven to maintain better humidity levels for the plants. The solar panels provide shade, preventing the sun from drying and burning the crops, and reducing water evaporation from the soil. This setup is particularly beneficial for fruit crops like raspberries, blueberries, and strawberries. Another concept is to create wide rows between the solar modules, allowing large machinery to access and harvest the crops. Research shows that solar panels occupy only 15-30% of the land, yet they help reduce soil erosion and improve biodiversity (Polskie Stowarzyszenie Fotowoltaiki, 2023). Another way to create multipurpose benefits from solar farms is to combine them with biodiversity support. By creating wider rows between the photovoltaic (PV) modules and planting wild grasses and flowers, biodiversity in the area can be significantly improved. Conventional crop harvesting often relies heavily on fertilizers, which kill unwanted plant species but also harm beneficial insects and plants, thus not supporting biodiversity (Geisseler & Scow, 2014). In contrast, planting wild plants beneath the solar panels creates natural habitats for insects and small mammals. Research indicates that wild meadows established in solar farms attract various species of butterflies, insects, mice, and even small birds that nest in the metal structures of the PV modules (Parker & Mcqueen, n.d.). This method enhances the ecological value of solar farms while maintaining their energy production capabilities. These examples demonstrate the potential to develop multifunctional solar farms that support both energy generation and biodiversity. Although these ideas are still relatively new and not widely implemented, they are promising. It will likely take several years for such projects to become common in the market, but the benefits of both renewable energy and environmental conservation are clear.

1.1.4 Private companies

Nevertheless, most PV developments are currently driven by economic values. Private companies invest in the most efficient modules without considering other types that might better support biodiversity or have less impact on local communities. As Kristian Borch mentioned in a conversation, the PV market does not prioritize communities; it is primarily seen as a business opportunity to generate extra revenue. Consequently, large-scale PV projects often face significant resistance from local communities (Borch-Personal Communication, 2024). Although many people support the national transition to renewable energy, limited research focuses on the local communities directly affected by PV development (Devine-

Wright, 2004). Additionally, while there is substantial research on resistance to onshore wind power plants, there is limited research on the impact of photovoltaic power plants on nearby areas. This project addresses the issue of cancellations or delays in large-scale PV projects due to local resistance.

1.1.5 Summary

Therefore, this master project aims to understand the various types of photovoltaic modules and the services they provide by examining both their technical features and their social impacts. The paper will highlight aspects of resistance and acceptance, exploring how planners can address people's needs while meeting energy and environmental targets.

The 2. Problem Analysis will define photovoltaics and describe three different types available on the market. It will also introduce the concepts of acceptance and energy communities. The 3.1 Theory will present theories that inform the analysis of technologies and the stakeholders involved in developing PV farms. The 3.2 Methods will outline the methods used in this project, such as Horizontal Scanning, Document Analysis, and Interviews. Chapter 4. Discussion and Results provide an analysis comparing the PV modules and develop two business models, focusing on non-profit cases and their social benefits. It will also explore the advantages and disadvantages of different PV modules summarised in the scorecard. The 5. Conclusion chapter will discuss the PV market, demand, private developers' approaches, and the environmental impact of PV technology. The final chapter will present the research conclusions.

1.2 Research questions:

The research questions will be provided to emphasize the objectives and scope of the study, serving a vital role in guiding and focusing the research. Additionally, they help in selecting appropriate methods and tools. The research questions are as follows:

1. **How can planners and developers mitigate the risk of halting or delaying PV solar farm projects by increasing community acceptance?**

Sub-questions:

2. How can planners and developers modify their approaches to effectively handle environmental and social concerns and lower the probability of project delays?
3. In what ways do different kinds of solar modules serve different needs or functions?

2. Problem Analysis

This project aims to delve into the development of photovoltaic farms, a domain witnessing intense competition among private developers vying for land to establish new solar facilities (Englund- Personal Communication, 2024). The energy landscape has evolved rapidly over the past four years, with municipalities now inundated with approximately 30 applications annually, compared to just three, four years ago. This increase in applications highlights the intense rivalry that developers face when trying to find adequate property for solar farm projects (Englund- Personal Communication, 2024).

Recognizing the importance of preserving and enhancing biodiversity alongside renewable energy infrastructure is thus paramount. However, amidst this fervor for solar farm development, there exists a visible resistance among local residents living in close proximity to proposed sites (Devine-Wright, 2004). These individuals exhibit reluctance towards embracing such investments, often resorting to tactics aimed at delaying or thwarting the development process (Englund- Personal Communication, 2024; Henckel- Personal Communication, 2024). This resistance underscores the need for planners to explore strategies to address and mitigate the challenges associated with the cancellation or delay of PV farm projects.

In light of this, this master project aims to provide useful information on how planners may overcome and lessen barriers to the profitable expansion of PV farms. Planners can be crucial in making sustainable and socially acceptable renewable energy projects a reality by identifying the causes of opposition and creating focused plans to address community concerns. The initial step of this research will involve delving into the technology of photovoltaics, tracing its origins and development over the years. Subsequently, the focus will shift towards exploring various types of photovoltaics, offering citizens the opportunity to make informed choices. Furthermore, this investigation will extend beyond merely examining the technical specifications of PV modules to encompass the array of services they provide, including economic, energy, environmental, and social aspects, and the corresponding value they deliver to society. As highlighted by C. Henckel, a city planner from Vordingborg commune, empowering people to participate in decision-making processes is crucial for fostering a sense of comfort and ownership over project choices (Henckel- Personal Communication, 2024). Therefore, this project will explore diverse types of PV modules to offer a range of choices in the establishment of large-scale PV farms, thereby enhancing community engagement and acceptance.

2.1 Photovoltaics

The technology behind photovoltaics dates to 1954 when the solar cell was first developed. Despite initially high production costs, its efficiency, reliability, and lightweight nature made it ideal for powering satellites in space. The widespread adoption of PV systems began in earnest in 1973 during an oil crisis and gained further momentum following the Chernobyl disaster in 1986. Today, amidst concerns over energy security and environmental sustainability, the popularity of photovoltaics continues to grow (Häberlin, 2012).

Solar power is harnessed through photovoltaic cells, which, as their name suggests, convert light (Greek: "phos") into electricity (Greek: "volt"). A photovoltaic power plant encompasses more than just the photovoltaic modules; it also includes essential components like electrical cables, transformers, and other necessary equipment (Winther, 2020).

2.2 Ground-mounted PV

The sun positioned approximately 150,000,000 km away from Earth, sends its light to our planet in just 8 minutes and 20 seconds. Despite its immense distance, only half of the sunlight that reaches the Earth's surface is actually absorbed, with the other half either reflected back into space or absorbed by the atmosphere. This makes the sun an incredibly potent source of energy. However, for many years, solar energy took a backseat to more accessible sources like coal and gas for energy production.

In the wake of environmental concerns, there's now a heightened focus on renewable energy sources, with photovoltaic technology emerging as one of the most promising solutions (Winther, 2020).

The efficiency of such a PV farm relies heavily on the availability and quality of the energy grid in the area. Compliance with network requirements, particularly regarding power quality, is crucial (Hernández-Callejo et al., 2019). Furthermore, the connection of the PV system to the utility grid must be carefully evaluated to prevent any potential instability (Mustafa et al., 2020).

Furthermore, recent calculations by Ember regarding PV installations show that solar power has experienced the largest increase in capacity over the years. Solar power has added twice as much new energy as coal, rising from around 10 TWh in 2010 to over 1700 TWh (Wiatros-Motyka et al., 2024).

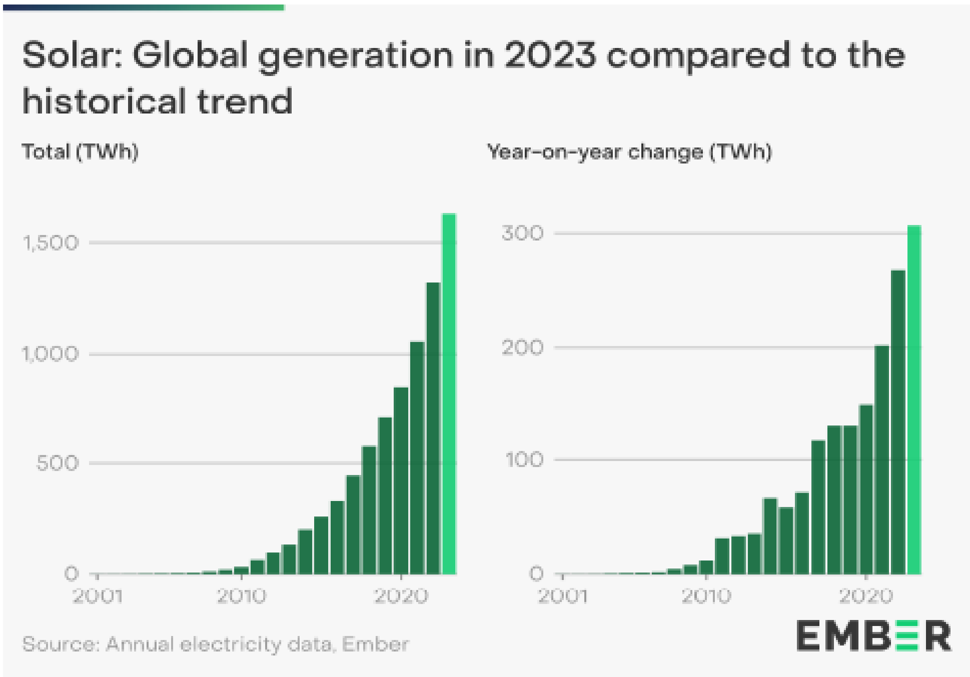

Figure 4- Global generation in 2023 compared to the historical trend (Wiatros-Motyka et al., 2024)

In comparison, the Ember group argues:

"Solar generation in 2023 was more than 6 times higher than in 2015" (Wiatros-Motyka et al., 2024) *p.74)*

However, to meet the net zero targets, solar power needs to grow more than five times by 2030. This means that its share in global energy generation, currently at 5.5%, should increase to 22%. While the trajectory is currently promising, it is important to maintain stable growth and keep a close eye on progress (Wood Mackenzie, 2023).

2.2.1 Technical Features

In the book "Visual Guide to the Power Grid: Inside the Greatest Machine in the World", the author vividly describes the photovoltaic cell as resembling a sandwich made of silicon crystals. Silicon, a semiconductor, transforms into a perfect conductor when energized, such as by sunlight. This energization initiates the flow of electrons between two layers, thereby generating electricity. To sustain this flow, a negative charge is introduced to the upper layer while a positive charge is applied to the lower layer. Consequently, the upper layer seeks to "donate" electrons while the lower layer endeavors to "acquire" them. When sunlight strikes the cell's surface, covered by glass, electrons are set in motion, freely moving between two layers of silicon. The upper layer, accumulating surplus electrons, directs them to the transformer and subsequently to the load. Electrons from the load then return to the lower layer, completing a closed circuit. This cycle ensures no electrons are lost, yet electricity is produced through their motion (Christian Dahl Winther, 2020). Furthermore, crystalline silicone material meets the highest standards for efficiency, durability, and cost-effectiveness future for PV modules (Benda & Černá, 2020).

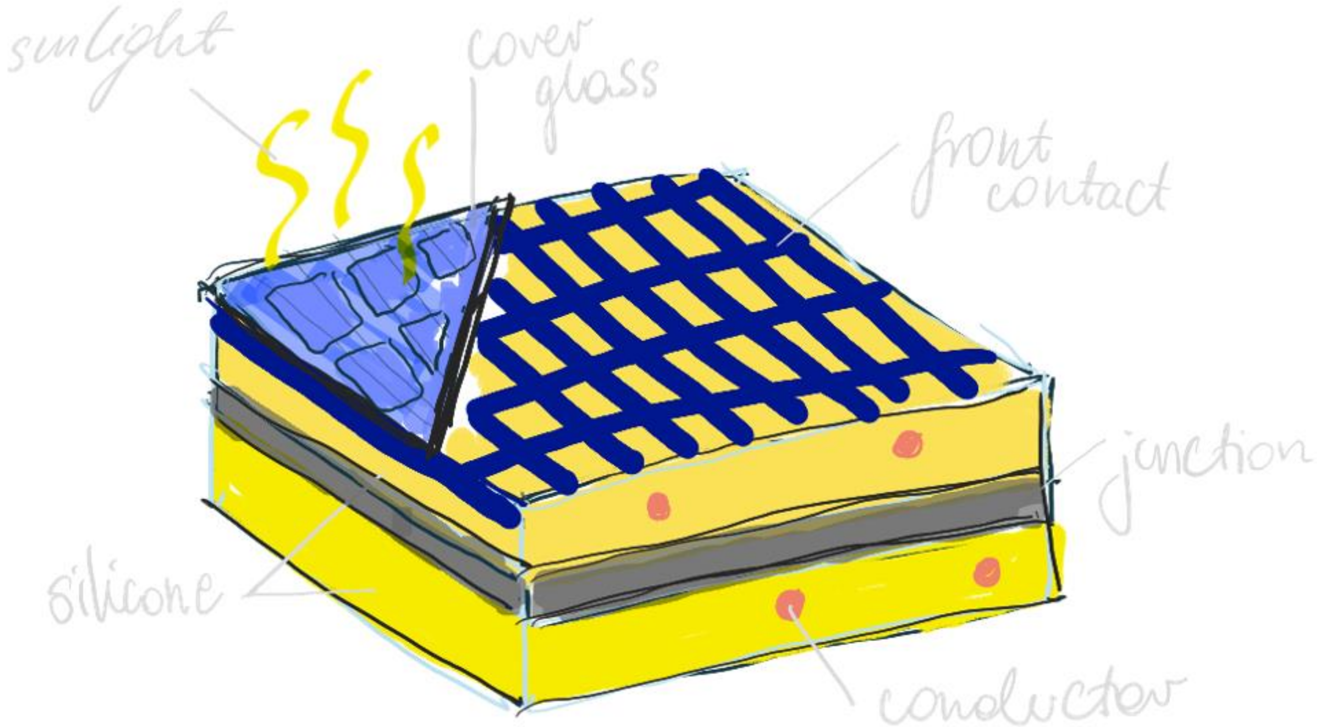

Figure 5- Photovoltaic cell

In the past two decades, technological advancements have significantly reduced the production costs of PV systems. Concurrently, PV modules have become increasingly efficient, while the reliability and yield of these systems have shown consistent improvement year after year. These developments have led to a decline in electricity prices, driven by the enhanced efficiency of PV panels (Benda & Černá, 2020). The National Renewable Energy Laboratory (NREL) conducted research on the prices of PV modules, as illustrated in the graphs below from the U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020 (Feldman et al., 2020).

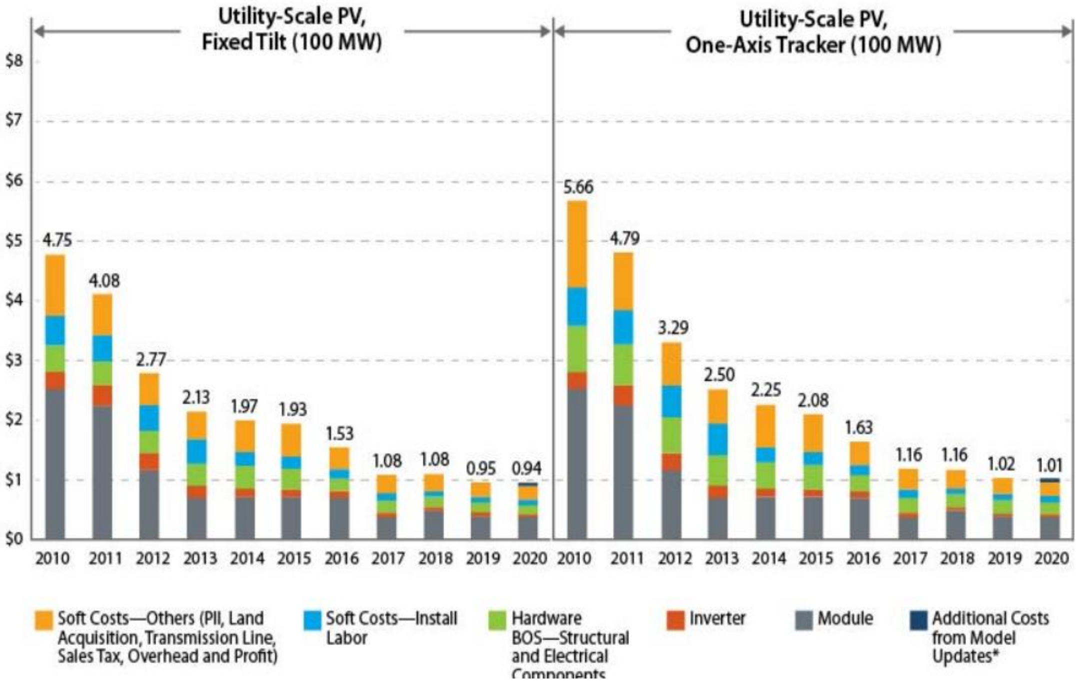

Figure 6- Prices of one-axis trackers over 10 years (Benda & Černá, 2020)

The decrease in prices of one-axis trackers by over six times signifies a huge opportunity for developers to install solar farms at lower costs while achieving higher efficiency. Despite the additional cost incurred between 2019 and 2020 due to model updates, the expense of upgrading technology did not outweigh the overall decrease in PV module prices (Benda & Černá, 2020). Furthermore, Ember has observed that solar prices are decreasing even more rapidly than the historic trend had anticipated (Wiatros-Motyka et al., 2024).

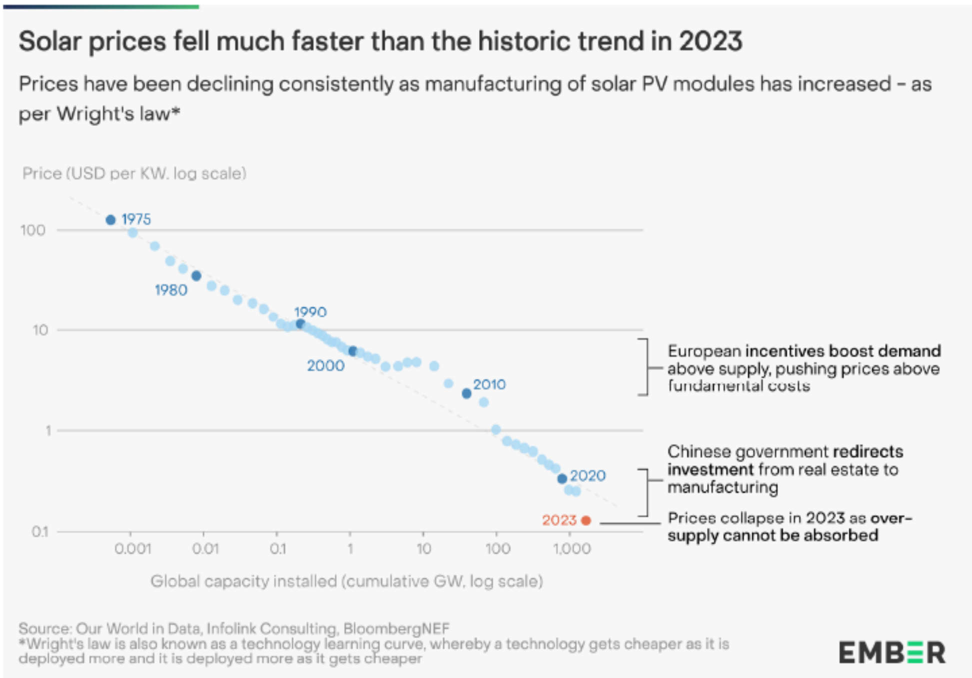

Figure 7- Solar prices fell much faster than the historic trend in 2023 (Wiatros-Motyka et al., 2024)

As PV module prices became increasingly appealing to buyers and developers, the popularity of photovoltaics surged. According to the authors of the “PV Cells and Modules – State of the Art, limits, and

Trends," the cumulative capacity of newly installed PV power plants skyrocketed thirtyfold between 2009 and 2019 (Benda & Černá, 2020).

The PV modules boast a relatively long service life. According to the authors of the article "PV Cells and Modules – State of the Art, Limits, and Trends" the minimal ground-mounted PV life service is 15 years. However, as explained in the book "Photovoltaics: System Design and Practice" by Heinrich Häberlin, the average PV life spans 25-30 years (Benda & Černá, 2020; Häberlin, 2012). Even while PV farms don't operate for as long as fossil fuel power plants, their longer lifespan allows them to produce green energy for many years.

Despite this, as society moves toward cleaner energy sources, PV farms are essential to promoting sustainability and lowering greenhouse gas emissions. As summarized in the article "Photovoltaics" by Niels Jungbluth, Matthias Stucki, and Rolf Frischknecht, photovoltaics offer several major advantages:

- Solar power is inexhaustible and will never end.
- Solar panels do not emit any hazardous gases or other environmentally unpleasant particles.
- There are no moving parts, so they do not produce any noise.
- Photovoltaics are very flexible and can be applied to various forms and shapes, serving as small power generators for power banks or as huge power plants for entire villages.
- They can be used for decentralized energy production.
- Silicon, the primary material, is abundant and non-toxic.

However, there are also some disadvantages highlighted by the authors:

- The energy density is relatively low.
- Energy production is dependent on weather conditions and hours of visible sunlight.
- Land availability can be a limiting factor for large power plants.
- The production chain is complex and cannot be localized

(Jungbluth et al., 2009).

2.2.2 Environmental Impact

Photovoltaics offer numerous advantages, yet they also come with certain drawbacks. In the article titled "Environmental Impacts on the Performance of Solar Photovoltaic Systems," the efficiency of solar panels was examined under adverse conditions such as dust accumulation, bird droppings, shading, and high temperatures. Surprisingly, the authors also found that water droplets had a positive effect on the performance of PV modules (Mustafa et al., 2020). The most significant factor affecting solar panel performance is shading. According to the article shading by a quarter, half, and three-quarters respectively decreases energy production by 33.7%, 45.1%, and 92.6%. The authors also noted that bird droppings, acting as shading, could cause up to a 7.4% decrease in energy production (Mustafa et al., 2020). Following shading, dust accumulation emerges as the second most influential factor, varying based on geographical location. In regions like the Middle East, characterized by dry, sandy climates, dust accumulation is particularly severe. In the study cited in the article, the Gholami experiment revealed that solar panels left uncleaned for 70 days without rain experienced nearly a 22% decrease in PV performance. This underscores the importance of regular cleaning, with even weekly maintenance recommended. Interestingly, water droplets have a cooling effect, positively impacting solar panel performance. The authors demonstrated that water droplets can enhance PV power generation by 5.6%. Moreover, it's noted that a decrease in temperature by 1 degree Celsius increases PV performance by 0.33%. Conversely, the performance of PV panels suffers in very hot environments (Mustafa et al., 2020). The performance of PV panels depends on weather conditions and geological positioning, necessitating wise planning and maintenance. Thanks to new technology, there are more options to install solar panels, including one-axis and two-axis modules, and tracking the sun.

In conclusion, photovoltaics—which primarily use ground-mounted PV modules—remain one of the top sources of renewable energy. However, photovoltaics might be used in other ways due to growing energy and environmental requirements.

When positioned at the ideal angle to gather the most sunlight, ground-mounted photovoltaic modules are generally considered the most efficient alternative. Studies like "Vertically mounted bifacial photovoltaic modules: A global analysis" highlight how important orientation is for efficiently utilizing solar energy (Guo et al., 2013). More specifically, PV modules work far better when oriented so that they are perpendicular to the sun's rays. "Analysis of the optimum tilt angle for a soiled PV panel" points to an appropriate tilt angle of about 26 degrees for ground-mounted systems in Europe, where solar energy use is widespread. To ensure the best possible energy yield all year round, this angle is meticulously adjusted to consider variables including panel cleanliness, seasonal fluctuations, and geographic location. Following these empirical results can lead to increased solar energy system performance (Xu et al., 2017).

Table 1- Comparison of services provided by ground-mounted PV modules

	Economic		Energy production		Environmental		Social	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Ground-mounted	Reduction of cost through the years, reducing reliance on centralized energy sources, easy for maintenance	Life range max. 30 years, dependent on weather,	Abundant and renewable energy source, the most efficient type of PV, dual-use: Agro PV	Depending on the environmental aspects, low efficiency in dusty areas needs regular maintenance	Can be installed as Agro-PV	Ground impact, need large areas	Generate big amount of electricity in the local area, cheaper electricity, most known type	Big visual impact, competition between energy generation and agriculture,

Large PV farms often face criticism from local residents due to their perceived impact on the surrounding environment. Research conducted in Portugal sheds light on community concerns regarding the visual disruption and potential harm to local ecosystems posed by PV solar farms. In response to these concerns, it is imperative to explore alternative approaches beyond ground-mounted PV modules (Botelho et al., 2017). Contemporary efforts by developers are increasingly focused on investing in biodiversity PV farms or Agri-PV projects, aiming to mitigate environmental impacts while harnessing solar energy. However, to truly empower communities and address their concerns, a more inclusive approach is needed.

This master project recognizes the importance of offering real choices to residents and minimizing the visual and ecological footprint of solar installations. Therefore, in addition to ground-mounted systems, transparent and vertical photovoltaic technologies will be integrated. By introducing these innovative solutions, the project seeks to strike a balance between renewable energy generation and environmental preservation, fostering greater acceptance and participation from local communities.

2.3 Transparent PV

Transparent Photovoltaic (TPV) systems have garnered considerable attention in recent years, primarily owing to the staggering energy consumption within buildings, which currently accounts for a substantial 40% of global energy usage (Lee et al., 2020). These innovative systems typically come in two primary types: visible light absorption and semi-transparent PV (Lee et al., 2020). The future can be visualized, when conventional windows in buildings are replaced with TPVs, offering the potential to generate over 40% of a building's energy consumption. Such a transition not only promises significant energy savings but also opens avenues for sustainable energy production within urban environments. Moreover, the applications of TPVs extend beyond traditional buildings; they can be seamlessly integrated into greenhouses, offering the possibility of self-powered systems for efficient smart farm management.

However, the journey towards widespread adoption of TPVs is not without its challenges. Key considerations include achieving high power conversion efficiency while maintaining transparency and color neutrality, ensuring modularization for ease of installation, and guaranteeing long-term stability to justify investment costs. These factors are critical for TPVs to become a viable alternative to conventional windows and contribute significantly to energy generation on a global scale (Pillai et al., 2022).

2.3.1 Technical features

In visible light absorption technology, a fraction of visible light is transmitted while the remainder is absorbed to generate electricity. This delicate balance between light transmission and absorption is achieved through various methods such as thin-film technology, which reduces the thickness of the light-absorbing layer, or selective light transmission technology, where specific regions allow light to pass through while absorbing the rest. Central to designing efficient TPVs are factors like light transmittance and sheet resistance. Transmittance, essentially the surface area of the electrode that reflects light, is closely tied to optical shading loss. Maximizing the transmittance of PV panels is essential to ensure efficient energy capture. Similarly, reducing the electrode's sheet resistance is crucial as it directly impacts the TPV's fill factor and current density, crucial for gathering photo-induced carriers produced in the light-absorbing layer. In simpler terms, maximizing light collection while minimizing material losses is paramount for TPV efficiency. Moreover, the thickness of the electrode layer significantly influences the absorption of visible light. Thinner light-absorbing layers result in better light transmission. Various materials, including carbon nanomaterials, polystyrene sulfonate, and metals, can be utilized for this purpose. Among these, metal nanowires stand out due to their excellent conductivity and cost-effectiveness. In fact, recent research has highlighted the potential of metal nanowires as a promising solution for addressing resistive and power losses in TPVs (Lee et al., 2020). Thin-film TPVs, on the other hand, are considered low-cost alternatives due to their easy fabrication using methods like evaporation and spin coating. This makes them particularly attractive for large-scale production. In comparison to traditional opaque PV panels, the fabrication of thin-film TPVs is notably cheaper, further enhancing their appeal for widespread adoption. Despite these advancements, challenges persist, such as addressing failures due to oxygen and humidity exposure. Nevertheless, with ongoing research and development efforts focusing on improving efficiency, durability, and cost-effectiveness, the future looks promising for TPVs to revolutionize the way we harness solar energy and integrate it seamlessly into our built environment (Lee et al., 2020).

2.3.2 Building Integrated Photovoltaics

The amalgamation of photovoltaic systems into building structures, known as Building Integrated Photovoltaics (BIPV), presents a compelling avenue for improving energy efficiency and sustainability. Numerous studies have explored the performance and possibilities of various BIPV technologies, highlighting both their benefits and obstacles (Joseph et al., 2019). One notable discovery is the considerable potential for energy savings offered by naturally ventilated photovoltaic double-skin facades. These systems can save approximately 35% of electricity per year compared to alternative technologies. They also boast a capacity to generate 65 kWh/year per unit area, while also saving 50% of lighting electricity during winter months (Joseph et al., 2019). Furthermore, research suggests that incorporating semi-transparent photovoltaic modules into BIPV systems can further enhance energy efficiency. Modules with 80% coverage of solar cells have been shown to increase energy efficiency by up to 7.6% compared to opaque counterparts. Among various BIPV configurations, semi-transparent BIPV windows emerge as particularly effective in terms of overall energy-saving performance, offering both daylighting and electricity generation benefits. Economic hurdles are particularly significant, with the installation and implementation costs of BIPV systems often surpassing those of conventional PV systems. Social challenges also loom large, as many individuals remain unfamiliar with BIPV technology and hesitant to embrace it as a dependable energy source. Initiatives aimed at raising stakeholder awareness and providing training are crucial for overcoming these barriers and promoting the widespread acceptance and adoption of BIPV systems. However, despite the promise of BIPV, numerous challenges impede widespread adoption. Scholars such as Goh, Mousa, and Baljit have extensively explored these challenges, including technological limitations, insufficient financial support, high initial investments, and low awareness levels among architects and the general populace. Addressing these challenges is pivotal for expanding the BIPV market and increasing installation rates (Attoye et al., 2018; Baljit et al., 2016; Goh et al., 2015).

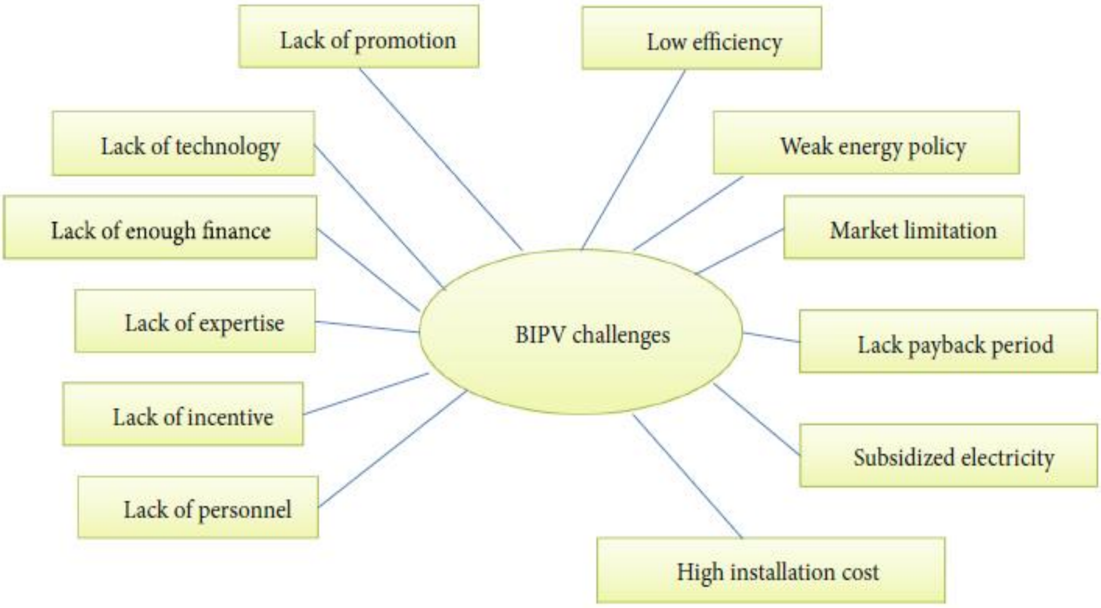

Figure 8- Challenges of Bifacial PV modules (Kumar et al., 2018)

In the article titled "Semitransparent Building-Integrated Photovoltaic: Review on Energy Performance, Challenges, and Future Potential," the author outlines a diagram illustrating the challenges faced by BIPV (Kumar et al., 2018). While technical hurdles are certainly part of the equation, there's a notable emphasis on social challenges as well. One significant social challenge is the lack of widespread understanding of semi-transparent PV technology. Many people are unaware of its capabilities and benefits, and there's a lack of promotional efforts to spread awareness. Governments and communities also aren't doing enough to incentivize the adoption of semi-transparent BIPV, which slows down its progress. Another issue is the confusion surrounding how to integrate photovoltaic modules into existing buildings. There's a lack of clear communication about the process and the services provided by these systems. Without proper guidance, stakeholders find it difficult to make informed decisions about implementing BIPV (Joseph et al., 2019).

In essence, the challenges facing semi-transparent BIPV go beyond technical complexities. They involve social factors like awareness, incentives, and communication. Addressing these challenges is essential for realizing the full potential of BIPV in creating more energy-efficient buildings. In summary, while BIPV holds immense promise for bolstering energy efficiency in buildings, tackling technological, financial, and social challenges is essential to realizing its full potential. Through innovative design approaches, heightened awareness efforts, and active stakeholder engagement, the integration of BIPV systems can play a pivotal role in advancing sustainable building practices and curbing the environmental impact of energy consumption.

2.3.3 Semi-transparent PV on Greenhouses

As previously noted in the introduction to this section, transparent photovoltaics have potential applications on the rooftops of greenhouses. However, in this scenario, the technology differs somewhat. Semi-transparent solar cells offer a solution that merges the benefits of visible light transparency with light-to-electricity conversion. These cells utilize materials distinct from fully transparent ones, employing mid-band-gap polymer materials, for instance, which can enhance performance compared to opaque cells (Emmott et al., 2015).

The unique combination of properties offered by semi-transparent photovoltaic (STPV) technology makes it highly attractive for greenhouse applications. Transparency, flexibility, and the capability for rapid, roll-to-roll manufacturing distinguish STPVs, allowing for innovative strategies such as partial shading, which has already proven effective with conventional PV modules. Research indicates that maintaining an optimal PV coverage of 20-30% on greenhouse roofs does not impede crop growth (Emmott et al., 2015). This approach can be further optimized by incorporating semi-transparent PV modules or reflective coatings on greenhouse glass, facilitating the targeted delivery of specific wavelengths to plants while simultaneously generating electricity. However, a key challenge lies in refining the absorption spectra of semi-transparent modules (Emmott et al., 2015). Furthermore, the compatibility of STPV technology with greenhouse materials, particularly low-density polyethylene, offers the prospect of cost-effective integration. The harmonization of STPV substrates with greenhouse structures holds promise for substantial cost reductions and rapid mitigation of carbon emissions. The performance of solar cells, including STPVs, hinges on their band gap, which governs the open circuit voltage. Through advancements in materials science and engineering, researchers are striving to optimize STPV performance, ensuring its competitiveness in the dynamic realm of renewable energy and sustainable agriculture. Nonetheless, technical analyses indicate that semi-transparent STPV devices may encounter difficulties in competing with traditional opaque crystalline silicon panels (Emmott et al., 2015).

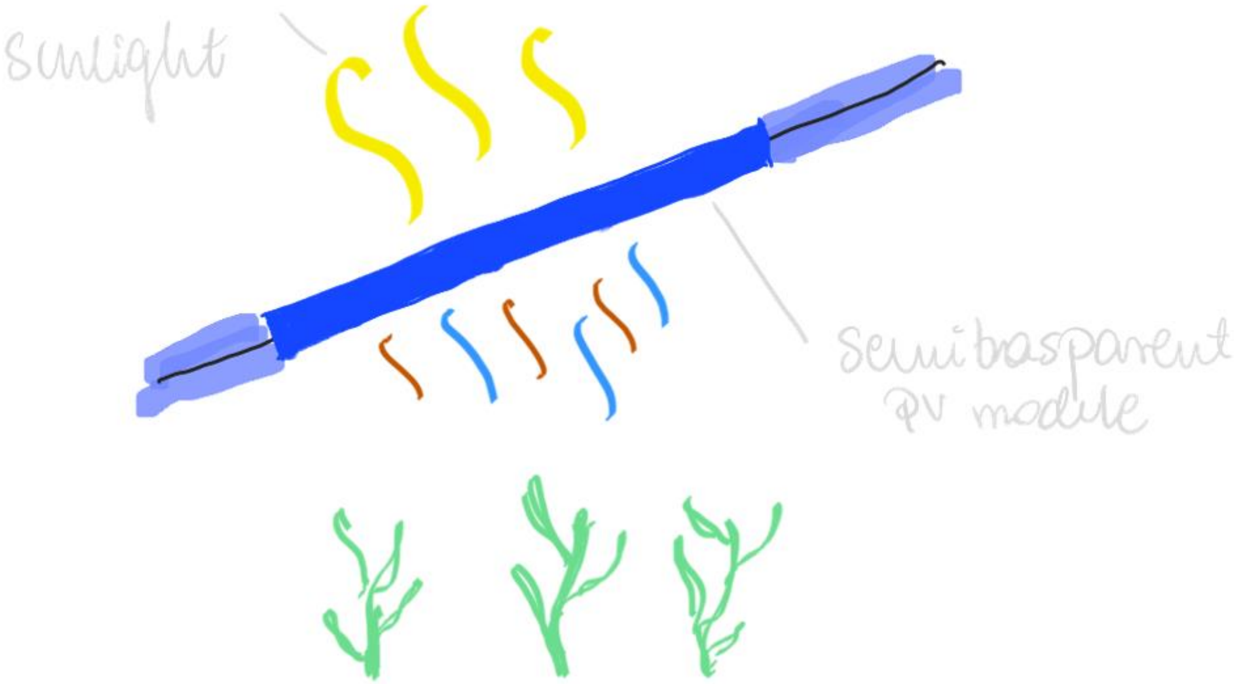

Figure 9- Transparent Photovoltaic Module

2.3.3.1 Plant growth

Understanding the photosynthetic needs of crops is vital for effectively balancing electricity production and crop growth in greenhouse environments. Different crops have varying requirements regarding sunlight exposure; while some thrive with increased sunlight, others, such as basil or poinsettia, prefer lower light levels. This understanding allows for a meticulous analysis of the correlation between reduced rates of photosynthesis and subsequent crop growth reduction, aiding in decision-making regarding optimal lighting levels tailored to different crops and climates. Photosynthesis primarily utilizes light within the wavelength range of approximately 400 nm to 700 nm. However, not all wavelengths are equally efficient in driving photosynthesis, with distinct peaks in the rate of photosynthesis observed in the red and blue regions of the spectrum (Emmott et al., 2015). Moreover, it is assumed that for every 1% decrease in the rate of photosynthesis, there is a corresponding 1% reduction in crop growth within the greenhouse. This metric provides a framework for evaluating the balance between crop productivity and electricity generation. However, it is important to note that this principle is applicable primarily to crops that benefit the most from increased sunlight exposure (L.F.M. Marcelis, 2006). The study called "Organic photovoltaic greenhouses: a unique application for semi-transparent PV" found that with an active layer as thin as 5 nm and an appropriate choice of contact materials, the maximum achievable crop growth factor reached 88%. This highlights the importance of material selection in optimizing crop yield in greenhouse settings (Emmott et al., 2015).

2.3.3.2 Effectiveness

Materials characterized by low band gaps are favored for their ability to generate higher current, primarily due to their increased absorption in the visible spectrum. Consequently, these materials tend to produce more current for a given device thickness, leading to enhanced performance. In the same article, the authors conducted a comprehensive comparison of various aspects of semi-transparent photovoltaic (STPV) technologies, including efficiency, cost, lifetime, and overall performance. They examined three distinct types of STPV technologies: the Best Line, Base Line, and Very Low-cost PV (Brian Azzopardi, 2011). One notable finding was the relatively low lifetime of these STPV technologies compared to ground-mounted PV systems, with a maximum lifespan of 10 years, compared to the standard 30-year lifespan of ground-mounted PV systems. Even the Base Line and Very Low-cost PV technologies exhibited a shorter lifespan of only 5 years, which raised concerns about their long-term profitability. Moreover, the authors discovered that both the Best-case and Very Low-Cost PV scenarios resulted in significantly reduced device efficiencies, measuring at 2.1% and 1.31%, respectively. This underscored the importance of achieving higher efficiencies for STPV greenhouses to be financially viable in the long run (Brian Azzopardi, 2011; Emmott et al., 2015). While the use of pricier materials in the Best-Case scenario led to enhanced absorption, it also brought about a substantial price difference. The Best-Case scenario was estimated to cost around 30 Euros per module, while the Very Low-cost PV option was considerably more affordable, priced at approximately 6 Euros per module.

To sum up, regardless of the absorption capabilities of the active layer, all devices will exert some influence on crop growth. To rationalize the increased costs per square meter for STPV modules, it becomes imperative to demand higher efficiencies. Opting for devices with lower transparency but higher efficiency might find optimal application in greenhouses cultivating specialty crops. These crops, such as tropical flowers, are capable of enduring reduced light levels, withstanding up to a 50% decrease in illumination in specific climates (Emmott et al., 2015). Investing in low-cost modules presents an opportunity to enhance the value proposition of climate-controlled agriculture. For instance, integrating water pumping systems powered by these modules can optimize energy usage within greenhouses, rather than solely focusing on selling excess energy to the grid. This approach offers a practical solution for addressing on-site energy needs, thereby improving operational efficiency and sustainability. Conversely, opting for more expensive yet highly efficient modules warrants consideration, especially when electricity typically constitutes only a fraction of a greenhouse's overall energy demand, ranging from 10% to 30%. Despite this relatively small portion, the electricity generated within a greenhouse structure holds significant value. An enlightening observation made by the authors underscores the potential impact of semi-transparent PV modules on greenhouse structures. They highlighted:

"If all polytunnels in China could be transformed into PV greenhouses, the 415 GWp of PV capacity this could provide, would supply almost 15% of the national electricity demand" (Emmott et al., 2015; Kacira et al., 2016).

This compelling statistic underscores the considerable power and potential of incorporating semi-transparent PV technology into greenhouse settings, not only for enhancing agricultural productivity but also for making substantial contributions to the overall energy landscape.

Table 2- Comparison of services provided by transparent and semi-transparent PV modules.

	Economic		Energy production		Environmental		Social	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Transparent	Thin-film TVPs are considered low-cost, dual use of windows	High price for implementation, more advanced technology, which is sensitive to oxygen and humidity exposure, hard to service	Power up the building it selves, lower load on the electrical network	Technical challenges of maintaining high efficiency and full transparency	No additional space is needed, and no environmental harm	Impact of changing actual windows for transparent PV ones	Promoting sustainable urban areas, no visual impact	Confusion surrounding the integration process, low awareness
Semi-transparent	Cost-effective for greenhouses, wide range of material pricing	Short lifetime, high installation cost, hard to service	Power up the greenhouse equipment, high efficiency when pricy material	When cheap materials the energy production is low, with lower efficiency than opaque modules	No additional space is needed, a combination of energy and plant production	Decrease of plant growth and production, challenge in terms of material selection over environmental impact	No visual impact creates sustainable adoption of PV modules on facades	Low lifespan and efficiency can lead to obstacles, low awareness

2.4 Vertical PV

When planning a solar farm, one of the foremost considerations revolves around the direction and orientation of the panels to maximize energy generation potential. Directing photovoltaic (PV) modules precisely toward the sun's radiant energy is pivotal (Dasgupta Ramboll & Dasgupta, n.d.) However, this task is complicated by the sun's constant movement, making it challenging to determine the optimal direction and orientation for a specific latitude and longitude. Vertical panels offer a unique solution by leveraging the natural angles formed by their placement to circumvent issues of tilt and alignment. This characteristic allows them to efficiently capture sunlight for extended periods, even as the sun approaches the horizon, ensuring a consistent electricity supply (Dasgupta Ramboll & Dasgupta, n.d.). Another crucial aspect influencing module efficiency is the amount of sunlight absorbed versus reflected. Lower reflection rates translate to better-performing cells (Li et al., 2011). Vertical panels excel in this regard, enabling them to harness more energy from both the sky and the ground, including sunlight reflected by the soil (Khan et al., 2017). This comprehensive method emphasizes how important it is to consider secondary sources of irradiance in addition to direct sunlight exposure when planning solar farms.

2.4.1 Technical features

In the realm of vertical photovoltaic (PV) modules, there exist two prominent types: mono-facial and bi-facial configurations. The distinction lies primarily in their design and capability to generate solar energy. Mono-facial modules are characterized by a single pair of electrodes and a layer of absorbing glass situated on one side of the module. This configuration allows the module to absorb sunlight solely from one direction. Conversely, bi-facial modules consist of two pairs of electrodes and absorb glass layers on both sides of the module. Essentially, they have the capacity to capture sunlight from both the front and back surfaces (Guo et al., 2013).

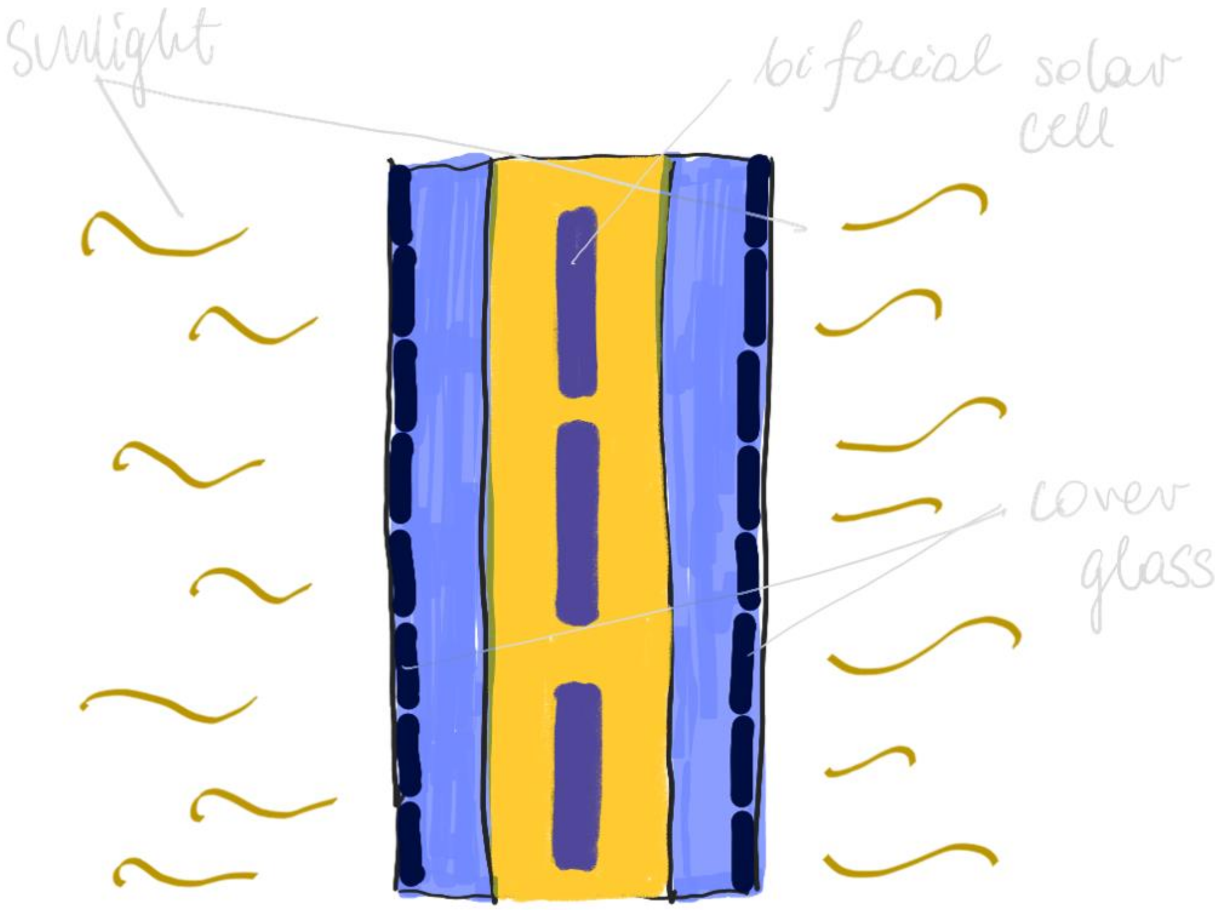

Figure 10- Vertical Photovoltaic Module

In a comprehensive analysis titled "Vertically mounted bifacial photovoltaic modules: A global analysis", researchers underscore the remarkable potential of bi-facial PV modules. Their findings suggest that bi-facial modules can generate up to 20% more energy compared to their mono-facial counterparts. This significant increase in energy yield underscores the effectiveness and innovation embodied by bi-facial PV technology (Khan et al., 2017). The objective of this master project is to investigate bi-facial photovoltaic (BIPV) modules in further detail, as they represent a more efficient and promising market niche in the solar energy industry.

Notably, bi-facial modules exhibit a distinct temporal advantage, yielding two peaks of daily radiance — one in the morning and another in the afternoon. This temporal alignment with peak electricity demand patterns underscores their efficiency and relevance in the contemporary energy landscape (Khan et al., 2017). Furthermore, the economic justification strengthens the argument in favor of the adoption of bi-facial PV. As the previous research clarified, bi-facial modules have production costs that are comparable to those of their mono-facial counterparts, in contrast to conventional modules. This production cost parity is a critical turning point for bi-facial technology, allowing for broad deployment without unaffordable costs (Khan et al., 2017). Yet, the advantages of bi-facial PV modules extend beyond mere efficiency and cost-effectiveness. In "Vertical bifacial solar farms: Physics, design, and global optimization," researchers illuminate the ancillary benefits, including environmental stewardship and space optimization. BIPV shading not only decreases ambient air temperatures by a notable margin but also occupies less ground space compared to traditional ground-mounted PV installations. This spatial efficiency translates into a tangible increase in energy yield, ranging from 5% to 20%, further amplifying the economic viability of bi-facial PV deployments (Khan et al., 2017). Another pivotal advantage lies in the inherent self-cleaning properties of bi-facial modules, as underscored by their unique orientation angle relative to the ground. This design feature mitigates dust accumulation, significantly reducing maintenance costs and ensuring optimal performance over the module's lifespan. The ease of accessibility further enhances the appeal of bi-facial PV technology, facilitating seamless maintenance and repair procedures compared to more inaccessible installations such as transparent PV integrated into high-rise buildings.

2.4.1.1 Geographical location

On the other hand, the efficiency of Bi-facial Photovoltaics (BPV) is intricately linked with the geographic location, particularly in relation to the distance from the equator. When the latitude is closer to the equator, the efficiency of vertically mounted panels tends to be inferior to ground-mounted ones. This discrepancy is largely influenced by the shadows cast by the vertical modules. In regions ranging from 0 to approximately 30 degrees latitude, the modules need to be positioned closer together due to the relatively smaller tilt of the sun. However, as latitude increases, the spacing between modules should also increase accordingly (Khan et al., 2017). The study titled "Vertically mounted bifacial photovoltaic modules: A global analysis" offers valuable insights gleaned from an extensive examination across various regions worldwide. Through their analysis, the authors constructed a comprehensive world map delineating where BPV outperforms ground-mounted PV (GMPV). Notably, regions near the equator exhibit greater efficacy with GMPV. This pattern includes wide regions of South America, the United States, South Africa, Australia, China, and India, as well as European countries like Spain and Italy (Guo et al., 2013). Conversely, in northern European regions, BPV demonstrates superior performance over conventional PV panels. This phenomenon is particularly pronounced in Nordic countries where the sun's inclination is higher, rendering bifacial PV modules more effective than ground-mounted installations. Similar trends are observed in regions such as England, central Europe (including France and Germany), as well as Russia and Canada. Additionally, vertical panels offer resilience against heavy snowfall, as the snow tends to slide off rather than accumulate on the surface.
Nevertheless, there exists a notable exception to this general pattern, notably in Northern Africa and Saudi Arabia. Despite their proximity to the equator, the analysis reveals that vertical modules exhibit greater effectiveness in these regions. This anomaly can be attributed to the prevalence of desert landscapes, where the accumulation of dust on conventional PV panels poses a significant challenge. Vertical modules, with their self-cleaning properties, prove advantageous in such environments, as the sand easily falls off the surfaces (Guo et al., 2013).

In conclusion, the performance of bi-facial solar panels varies greatly according to the location, with some regions showing better results than others. But when we focus only on the northern region of Europe, the findings seem especially encouraging. Furthermore, the choice to purchase such technology depends on the precise results desired. Vertical panels provide flexible options for integration into a range of infrastructure projects, beyond their conventional use in energy generation. For example, they can be placed in an aesthetically pleasant manner in metropolitan areas or as sound barriers alongside roads. This dual purpose helps with environmental sustainability and urban development projects in addition to improving energy output.

Table 3- Comparison of services provided by vertical bi-facial PV modules.

	Economic		Energy production		Environmental		Social	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Vertical bi-facial	Cost-effective, increased energy yield, space optimization, self-cleaning, low maintenance costs	Market uncertainty is not effective in many countries	Greater energy generation in northern parts of the world, resilient to environmental factors	Location dependency	Space efficiency, the possibility of dual-use	Land use impact, soil contamination	Greater yield production from smaller land-acceptance	Visual impact, land acquisition, low acknowledgment

2.5 Summary

The comparison between unconventional PV types and traditional ground-mounted PV modules reveals a nuanced landscape of advantages and disadvantages. While unconventional types may excel in certain aspects, they often face challenges related to cost-effectiveness and payback balance, as emphasized by S. Englund, land developer manager at GreenGO Energy. According to him, the cost of implementing new technologies remains prohibitively high, with extended payback periods rendering them less feasible in the current market (Englund- Personal Communication, 2024). Additionally, he argues that initiatives such as promoting biodiversity, utilizing the land for both harvesting and solar energy or implementing transparent PV on greenhouses, while environmentally beneficial, currently lack profitability and fail to attract investors. Instead, he advocates for the construction of large-scale PV farms capable of generating substantial energy output, thereby contributing to a greener future (Englund- Personal Communication, 2024). However, if resistance persists against such expansive projects, an alternative approach could involve the creation of smaller-scale and unconventional PV installations. This raises the question: Is it preferable to implement numerous smaller-scale projects, even if they deviate from conventional norms, rather than forgoing PV development altogether in the face of resistance to large-scale developments? This conundrum highlights the significance of finding a balance between lofty targets for renewable energy and the actualities of market dynamics and public acceptability.

2.6 Acceptance

Kristian Borch's article "Mapping value perspectives on wind power projects: The case of the Danish test center for large wind turbines" highlights a crucial distinction: while there may be national interest in renewable energy, this doesn't always align with local interests (Borch, 2018). He argued:

"In many cases, the impact of technologies on society is underestimated, especially the impact on those actors who are influenced by technological change but without perceived benefit." (Borch, 2018).

Establishing Net Zero regulations reflects a national focus on reducing hazardous gas emissions (Wiatros-Motyka et al., 2024). However, as Borch notes, there's often a disconnect between these national goals and the interests of local communities directly affected by the technology. In many cases, the benefits of renewable energy projects accrue to remote investors rather than the local community, despite regulations mandating some benefits for municipalities (Borch, 2018). To achieve national targets, it's crucial to gain acceptance from local communities; without them, these targets may be unattainable. Clear communication from developers and municipalities, along with trust-building efforts and technical knowledge dissemination, are essential to foster acceptance and avoid controversy (Borch, 2018). Failure to address these elements can lead to anxiety and a lack of recognition among local residents, undermining the success of large-scale renewable investments. Therefore, the process of implementing new technological investments should involve a creative approach to minimize harm, ensuring that communities feel more comfortable and perceive increased value from these projects. As Borch observes, contemporary renewable investments often prioritize profit maximization and stakeholder value over benefiting local communities. To address this, it's recommended to adopt a value perspective using the Value Framework (den Ouden, 2012). This framework considers value propositions from economic, ecological, psychological, and sociological perspectives, aiming to create solutions that people truly appreciate and use (Borch, 2018). From a psychological standpoint, people value well-being and quality of life, which include aspects like livability, inner appreciation, and overall utility. On a sociological level, involving local communities in the decision-making process regarding PV investments increases acceptance. Empowering society by including them in decisions that affect them builds trust and understanding of expected outcomes. Research shows that projects involving local communities and generating benefits for local areas are more readily accepted than those lacking these aspects (Borch, 2018).

The model which is introduced in this master project is a combination of Wustenhagen et al's social acceptance triangle (Wüstenhagen et al., 2007), and den Ouden perspectives (den Ouden, 2012), condensing four dimensions into three. These include socio-political acceptance, which assesses policies related to renewable energy; community acceptance, which evaluates the integration of renewable energy within communities; and market acceptance, which gauges stakeholders' willingness to invest (Borch, 2018).

2.6.1 Resistance

The authors of the article "Social and Market Acceptance of Photovoltaic Panels and Heat Pumps in Europe: A Literature Review and Survey" conducted research on the primary barriers to establishing renewable energy sources, particularly PV solar farms, among citizens. Their study focused on several key aspects, including economics, knowledge, trust, business models, and legal issues. They identified three main dimensions: socio-politics, community, and market. According to their findings, the community dimension emerged as the most crucial factor, as it encompasses local acceptance and addresses the concerns of all stakeholders involved in the development process (Peñaloza et al., 2022). The market dimension, on the other hand, pertains to the relationship between consumers and investors, while the socio-political dimension is closely linked to policymaking. The authors argue that these dimensions are interrelated, and the acceptance of one dimension is contingent upon the acceptance of others. In other words, for a project to be effective and widely accepted, all dimensions must be addressed and accounted for. This holistic approach ensures that potential challenges and issues are mitigated, leading to greater social and market acceptance of PV solar farms (Peñaloza et al., 2022). Acceptance is a multifaceted concept that encompasses both passive and active dimensions. It's not merely about the absence of opposition but also involves the active involvement and adoption of stakeholders. In their questionnaire, the authors highlighted several concerns raised by respondents. Firstly, financial concerns were prevalent, with individuals expressing worries about initial costs, payback time, maintenance expenses, and potential impacts on property value. This financial barrier resonated strongly, reflecting people's apprehensions about the financial implications of investing in renewable energy. Another significant concern revolved around social acceptance, with respondents considering the perceptions of family, neighbors, and media. Questions arose regarding whether investing in renewable energy would enhance or diminish one's social status. Additionally, the availability of competent personnel emerged as a concern, indicating the importance of having knowledgeable professionals in the field, especially amidst high competition (Peñaloza et al., 2022). The authors contend that social acceptance is influenced by a combination of technological, economic, comfort, social, and environmental factors. Their findings suggest that while knowledge about renewable energy is generally sufficient in Europe, disparities exist across regions. For instance, in Latvia, a lack of representation of renewable energy technologies in the media was noted, which could hinder acceptance among citizens. This highlights the importance of effective communication and education strategies to enhance social acceptance of renewable energy initiatives. Apart from apprehensions regarding media portrayal, the regulatory environment pertaining to investments in renewable energy also significantly influences acceptability, especially in nations such as Latvia. There are many beliefs in this area that the legal system is too complicated and unsupportive of PV installations. The government's assistance is thought to be insufficient, and the permit process is seen as onerous. The process of investing in renewable energy initiatives becomes more challenging for individuals due to the aforementioned regulatory constraints (Peñaloza et al., 2022).

Overall, Borch's article and the related research underscore the importance of addressing all dimensions of acceptance—community, market, and socio-political—to ensure the successful and socially accepted deployment of renewable energy technologies (Borch, 2018; Peñaloza et al., 2022).

2.7 Energy Community

The emergence of energy communities marks a pivotal shift towards democratizing and centralized control of energy systems, embracing a multifaceted approach to both local empowerment and broader systemic change. These communities, composed of local energy producers and users, are catalyzing a paradigm shift in how energy is generated, consumed, and managed. With their primary aim being the advancement of energy democratization and decentralization, energy communities are poised to exert positive impacts not only within their immediate locales but also on the broader energy landscape (Johannsen, 2023).

The primary aim of the energy community is to channel the energy generated within it into the broader network, ultimately selling it to the supplier rather than solely consuming it for internal use. Within the community, the energy produced is distributed and shared among its members (Caramizaru et al., 2020). At the core of the energy community movement lies a suite of benefits poised to reshape the energy narrative. Chief among these benefits is the potential to reduce energy costs, foster energy independence, curtail greenhouse gas emissions, and promote the adoption of renewable energy sources. By fostering deeper connections with the local populace, energy communities serve as conduits for cultivating a sense of belonging and shared purpose, thereby fostering cooperation, creativity, and community cohesion. Moreover, they serve as vital platforms for organizing and engaging local stakeholders in the ongoing energy transition, enhancing communication channels, and facilitating informed decision-making processes (Johannsen, 2023). In the scholarly realm, a growing body of research underscores the pivotal role of local communities in shaping the trajectory of energy systems. Authors such as the one behind the paper titled "Planning and Modeling of Local Integrated Energy Systems" argue that the burgeoning interest in energy communities necessitates a reevaluation of planning frameworks to account for tangible impacts and benefits at the local level. By integrating insights from this research with complementary studies such as master theses exploring the social services facilitated by photovoltaics, municipalities stand to gain comprehensive insights for long-term planning practices (Johannsen, 2023). Furthermore, scholarly discourse emphasizes the indispensable role of municipalities in driving the energy transition agenda. In the article "Developing energy systems scenarios for municipalities- introducing MUSEPLAN," the author underscores the critical significance of municipal-level interventions, that municipalities represent the most apt spatial scale for formulating policies and strategies to address energy and environmental challenges. However, the realization of this potential is contingent upon the availability of robust modeling tools that can accommodate the diverse array of local conditions, stakeholder values, and preferences (Johannsen, 2023). Despite their crucial role, local governments grapple with a myriad of obstacles, ranging from a lack of expertise and access to appropriate instruments to navigating complex legal frameworks. Addressing these challenges necessitates concerted efforts to enhance capacity-building initiatives, streamline access to resources, and fortify the legal scaffolding underpinning local energy initiatives. In doing so, municipalities can assume their rightful place as vanguards of the energy transition, driving meaningful change at the grassroots level and beyond.

3. Methodology

3.1 Theory

3.1.1 Choice Awareness

In this project, the concept of choice awareness plays a significant role, particularly within the context of the transition from fossil fuels to renewable energy. This transition is crucial for spreading knowledge and awareness among the populace, both at the societal and individual levels. It involves implementing radical technological changes while also necessitating organizational and institutional adjustments. When presenting this project and discussing the opportunities and comparisons of various photovoltaic (PV) technologies, as well as the advantages and disadvantages of energy communities, it's essential to emphasize that citizens have real decision-making power within their neighborhoods. This underscores the importance of choice awareness and empowers individuals to actively participate in shaping their energy future.

The Choice Awareness theory advocates for the development of technical alternatives, feasibility studies grounded in institutional economics, and regulatory measures that consider competing interests and evolving democratic decision-making structures. In an article titled "Choice of Awareness," the author delves into the significance of having genuine choices. He contends that true choice entails having alternatives between two or more options, whereas a false choice presents the illusion of choice without meaningful alternatives. Furthermore, he highlights the notion that lack of choice equates to a lack of power, suggesting that empowering individuals with the belief that they always have a choice is essential. The author illustrates this concept by referencing situations where organizations or individuals manipulate perceptions of choice, convincing society that alternative options do not exist (Lund, 2014). For instance, he cites the example of Hobson's Choice:

"This power station or none!" (Lund, 2014)

This statement was directed at the people of Northern Jutland during a time of rising energy demand when the municipality sought to build a coal-fired power station. Consequently, the author emphasizes that cultivating choice awareness is crucial, particularly when pursuing political objectives, especially amidst major technical shifts. The author asserts that technological change necessitates concurrent transformations in knowledge, technique, organization, and product. Without changes in each of these dimensions, implementing radical change becomes challenging, potentially leading to a reversion to old technologies. However, the impact of change varies across different stakeholders. For instance, transitioning from a coal mine to a large photovoltaic (PV) farm represents a significant shift for workers in the coal industry but may not significantly alter the experience of electricity consumers (Lund, 2014).

Returning to the concept of influence wielded by certain entities, the exercise of power in a manner that shapes others' opinions about their interests and the appropriate means to advance those interests is often termed mind-controlling power. In this context, the Choice Awareness theory advocates for substantial institutional reorganization to counteract such influences and promote genuine choice and autonomy among individuals and organizations. The author advocates for raising Choice Awareness among municipalities by recommending the implementation of institutional alternatives that foster societal engagement, emphasizing that society does indeed have a choice. He argues that the decision-making process hinges on public participation and awareness of available choices, which can mitigate distrust of new technologies (Lund, 2014).

In essence, the cornerstone of the Choice Awareness theory lies in fostering a collaborative perception of different alternatives, thereby empowering individuals to recognize the presence of genuine choices. To encourage this theory among citizens, it should be promoted by advancing the presentation of technological solutions in various deliberations and decisions related to new projects and initiatives at all levels. This entails advocating for feasibility study approaches that integrate relevant political objectives and advocating for a thorough delineation of public regulatory actions to facilitate the development of new technologies (Lund, 2014).

3.1.2 Stakeholder analysis

In this master project, conducting a stakeholder analysis is essential. The development of photovoltaic (PV) farms involves various actors. Additionally, these actors possess differing levels of power within the PV development process. Stakeholder analysis is intricately linked to recognizing the influence wielded by various actors, whether individuals, groups, or organizations, on the decision-making process. It serves as a tool to assess the organizational environment and behavior within specific actions. Moreover, it enables an understanding of the interdependence among stakeholders, highlighting the significance of their intentions, agendas, relationships, and interests. This analytical framework provides insights into the resources owned by each actor and how they can leverage them, thereby defining opportunities to exert influence within a specific context. The overarching aim of stakeholder analysis is to comprehend these actors not only from an organizational standpoint but also in terms of their relevance and vested interest in a given project (Zsuzsa. B. R. Varvasovszky, 2000).

The book's chapter titled "Stakeholder Analysis: How to Do (or Not to Do)" delves into the pivotal role of stakeholder analysis as a comprehensive toolkit essential for unraveling the behaviors of actors within a specific project. The genesis of stakeholder analysis lies within the realm of development, rooted deeply in political theory. It emphasizes the significance of comprehending the dynamics of resource allocation, epitomized by the adage "who gets what, when, and how." Central to the author's argument is the initial step of gathering exhaustive information about each stakeholder influencing the decision-making process. Subsequently, assessing their relative importance and mutual perceptions illuminates key stakeholders' significance within the project landscape. Moreover, identifying stakeholders' interests, capacities, and willingness towards shared objectives informs strategic decision-making. Culminating this process is the creation of a stakeholder map, highlighting relationships, potential alliances, and their alignment with project outcomes (Zsuzsa. B. R. Varvasovszky, 2000). Stakeholder analysis underscores the importance of understanding stakeholders' motives and priorities, highlighting the nuanced factors shaping their engagement within the project framework. As a result, the perspectives provided by Reich highlight the complex and dynamic character of stakeholder analysis as a crucial procedure for well-informed decision-making and strategic alignment in project management settings (Reich, 1993). The primary analysis contends that many studies overlook the comprehensive nature of stakeholder analysis. Instead of conducting a thorough examination of stakeholders, their relationships, interests, and influence on decision-making processes, they often narrow their focus solely to the power of decision-making held by each actor.

Stakeholder analysis serves varied purposes, whether for project implementation, policy formulation, or achieving organizational advantages. Different purposes demand distinct approaches and varying levels of emphasis on categorizing relevant stakeholders. Therefore, tailoring the analysis to specific objectives is crucial for its effectiveness and relevance (Zsuzsa. B. R. Varvasovszky, 2000).

From a planning perspective, stakeholder analysis serves multiple functions, including informing, implementing, and evaluating planning projects. This theory aids in identifying stakeholders who stand to benefit, those who may be adversely affected, and those whose impact falls somewhere in between.

Categorizing stakeholders into primary and secondary actors becomes feasible through this process. In strategic planning, the emphasis lies on enhancing or diminishing the influence of potential decision-makers. The initial step in conducting stakeholder analysis within planning actors involves identifying the project's goals, areas of interest, and the underlying motivations driving its implementation. Equally important is understanding the project's potential impact on stakeholders and gauging their levels of interest and influence. This comprehensive approach lays the groundwork for effective planning and decision-making processes (Z. Varvasovszky & Brugha, 2000; Zsuzsa. B. R. Varvasovszky, 2000).

Stakeholder analysis is essential to this project since it helps to identify the wide range of players that are involved in the construction of large-scale PV farms. The goal is to create a comprehensive stakeholder map that highlights the importance of each significant stakeholder in advancing the project's growth while also identifying the most important ones through in-depth analysis. Strategic decision-making processes are informed by valuable insights into the interests, resources, and viewpoints of each stakeholder, which were obtained through evaluating their power dynamics and roles. By fostering collaboration, navigating potential obstacles, and successfully engaging with key stakeholders, this thorough grasp of stakeholder dynamics helps maximize the project's potential for success in promoting sustainable energy projects.

3.2 Methods

3.2.1 Horizontal Scanning

Horizontal scanning, a method used to carefully examine various types of photovoltaic modules, will be utilized in this master project within the context of landscape planning. Given my lack of specialized technical knowledge concerning photovoltaic features, this approach becomes essential. Additionally, drawing from the insights of "Governing emerging technologies—looking forward with horizon scanning and looking back with technology audits," horizontal scanning prioritizes examining legal, social, and ethical implications. This focus aligns with the aims of this paper, facilitating its thorough exploration and analysis (Greely, 2022).

Horizontal scanning has a rich history spanning various fields such as transport, genetic engineering, and environmental pollution. Initially, its definition was rather nebulous, emphasizing the need to gain a preliminary understanding of the potential advantages and disadvantages of technological applications. This explorative and open approach allowed researchers to tailor their investigations based on the specific objectives of their inquiry. The primary objective of horizontal scanning was to discern what remains constant and what changes over time in the technological landscape under analysis. Researchers could select a horizon period ranging from short to medium- or long-term, depending on their focus. However, as horizontal scanning evolved into a tool for identifying monetary benefits and commercial potential, the need for a more precise definition arose (Greely, 2022). The Organization for Economic Co-operation and Development delineated horizontal scanning as a technique for systematically identifying early signs of potentially significant developments. This process involves methodically examining potential risks and opportunities, with a particular emphasis on new technology and its impact on relevant issues (U.S. National Academies of Sciences, 2020). According to H. Greely, horizontal scanning involves multiple stages, including filtration, prioritization, assessment, and dissemination. These stages underscore the importance of conducting horizontal scanning in the early stages of new technology to gauge whether it is likely to emerge as a principal force in the future or to mitigate potential risks and maximize opportunities. Moreover, he highlights that the focus of horizontal scanning efforts should be on understanding why and how new technology can impact society, rather than specifying the exact manner of its adoption (Greely, 2022).

Researchers can better predict and negotiate the ramifications of emerging technologies by using an organized approach to horizontal scanning. This helps inform decision-making across a range of domains, including landscape planning. This thorough comprehension enables the development of more efficient methods for maximizing the advantages of emerging technologies while reducing any hazards and guaranteeing their appropriate assimilation into society. Despite its potential benefits, horizontal scanning remains unfamiliar to many individuals. Once new technology gains approval from the government or other entities and changes are implemented, there is often a tendency to overlook further technical research. This oversight can lead to various challenges, including the failure of new initiatives. Consequently, the outcome may either result in the abandonment of the new technology or, in some cases, companies may attempt to refine their initiatives without yielding any significant benefits (Gates, 1995; Greely, 2022). Additionally, forecasting the trajectory of new technology poses considerable challenges. Predicting how technology will perform over the long term, especially in response to external conditions and its interactions with other technologies, is inherently complex.

Take, for example, photovoltaic (PV) technologies. While a new PV cell technology may demonstrate exceptional energy generation capabilities, its success hinges on factors such as grid connectivity and the capacity of energy transformers to efficiently convert energy in various countries. Failure to address these complementary infrastructural elements could precipitate the collapse of a promising initiative. Recognizing the multifaceted nature of technological advancement, the author suggests that horizontal scanning teams should comprise individuals from diverse backgrounds, including researchers, entrepreneurs, academics, and most importantly, citizens—referred to as the "cloud on the horizon" in some instances of unveiling new initiatives. This inclusive approach ensures a comprehensive assessment of the societal implications and feasibility of new technologies. Moreover, horizontal scanning should not be a one-time aim but rather an ongoing process. Regular assessments, perhaps conducted every five years, are essential to maintaining a comprehensive overview of technological developments. The findings of these assessments must be meticulously documented, critically evaluated, and, if deemed necessary, applied. Disseminating these findings widely is imperative, not only due to their inherent legitimacy but also because of the profound ethical and social ramifications they may entail (Gates, 1995; Greely, 2022).

In conclusion, the implementation of horizontal scanning promises to significantly enhance comprehension of the three distinct types of photovoltaic technologies under examination in this project. By prioritizing an analysis that extends beyond mere technical and economic considerations, horizontal scanning enables a comprehensive exploration of the social and environmental implications associated with these technologies. This holistic approach is crucial for ensuring that the potential benefits of photovoltaic systems are weighed against their broader societal and environmental impacts. Thus, while optimizing the potential advantages of new technology, the dangers connected with their adoption are reduced. All things considered, horizontal scanning is an important instrument for furthering comprehension of solar technology and its wider applications. Adopting this methodology will help to manage the intricacies of technological innovation in a world that is constantly changing, promote sustainable growth, and make more informed judgments.

3.2.2 Document Analysis

Utilizing multiple data sources and employing at least two different data collection methods is essential in qualitative research. This strategy aims for convergence and corroboration, thereby enhancing the validity and dependability of study findings (Bowen, 2009). In this research, document analysis supplements understanding of the research topic. It provides insight into PV module technology, differences among divergent PV modules, and the development of PV in Denmark.

Document analysis involves systematically reviewing or evaluating both printed and electronic documents. In qualitative research, an analytical method is essential for interpreting obtained data to understand its meaning and gain empirical knowledge. Rather than mere data collection, qualitative research requires careful data selection. Document analysis proves effective as it can complement other methods, such as interviews. By examining information gathered through diverse methods, the potential bias of one-sidedness is mitigated. Bowen, in the article "Document Analysis as a Qualitative Research Method," emphasizes how document analysis can aid in uncovering meaning, fostering understanding, and evolving insights into a given problem. This underscores the method's significance in qualitative research and its ability to enhance the research process (Bowen, 2009).

Document analysis, as a qualitative research method, offers several advantages. Firstly, it is efficient, requiring less time compared to other methods. Additionally, it is widely accessible, particularly in an era where almost every article is available online, simplifying the search for relevant documents. Moreover, it is cost-effective and stable (Bowen, 2009; Merriam, 1988). However, despite its advantages, document analysis does have some drawbacks. For instance, the documents analyzed may lack sufficient details, leading to potential ambiguity. Furthermore, there may be instances where access to certain documents is restricted or blocked, presenting challenges for researchers. Lastly, documents themselves can be biased, potentially influencing the researcher's perspective or opinion. These limitations underscore the need for careful consideration and critical evaluation when employing document analysis in qualitative research (Yin, 1994).

This research is primarily based on a limited number of documents, with some inevitably being omitted. The process of conducting a horizontal scan posed challenges in selecting a sufficient number of articles to fully grasp photovoltaic technology. Additionally, the vast amount of documents pertaining to renewable energy makes it challenging to find specific research on the acceptance and resistance among citizens towards large-scale PV farms (Merriam, 1988). Despite these challenges, a thorough examination of documents has been undertaken. This examination considers various elements, including the original intent behind each document, the circumstances of its creation, and the target audience it was intended for. This demanding approach is crucial for upholding transparency and ensuring the validity of document interpretation in this research (Bowen, 2009).

3.2.3 Interview

The following section will detail the interview methodology employed in this project, which involved engaging with three distinct stakeholders involved in renewable energy development. Three interviews were conducted using a semi-structured approach, with one conducted in person and two conducted online via Microsoft Teams software. The decision to conduct online interviews was motivated by considerations of time efficiency and cost-effectiveness. However, it's important to note that this mode of interview may lack the ability to observe nuances in emotions and gestures. In this section, the rationale behind selecting these interview modes will be elucidated, along with a summary of the interviews conducted (Fleckner et al., 2023). The interviews were conducted with the aim of gaining insights into various facets of photovoltaic development within Danish municipalities. To achieve this, conversations were held with a PV developer and municipal planner as well as a professor from Aalborg University, representing urban planning domains. These interviews yielded valuable perspectives from different stakeholders involved in the development process, offering insights into the complexities of timeline investment and shedding light on the multifaceted nature of PV development.

Semi-structured *interview:*

The semi-structured interview method was chosen to harness the insights gleaned from document analysis and to delve deeper into the knowledge shared by interviewees regarding the challenge of mitigating resistance to PV modules. Unlike formal interviews with a predetermined set of questions, semi-structured interviews center around specific themes and allow for a more fluid conversation. These themes were crafted based on the insights derived from document analysis, ensuring alignment with the intended research outcomes (Raworth et al., 2012). This approach affords the opportunity to explore the motivations, choices, and behaviors of interviewees, as well as gain insights into their attitudes, beliefs, and the impact of specific events on their lives. By delving into individual experiences and perspectives, the semi-structured interview provides a nuanced understanding of the case under investigation. Moreover, it yields valuable information that may not have been uncovered through other research methods (Raworth et al., 2012). Each interview was meticulously recorded for future reference, and transcriptions were completed promptly after each session. As a result, the transcriptions faithfully capture the word-for-word exchanges that occurred during the conversations. These transcriptions, serve as a rich source of data for further analysis and interpretation. The guidelines for the interviews are located in the Appendix chapter.

Sonny Englund- Land Development Manager at GreenGO Energy

The interview with Sonny Englund took place on May 6th at the GreenGo Energy office in Vaedbek, situated in the Copenhagen region. Englund serves as the Land Development Manager, tasked specifically with obtaining permissions for large-scale PV farms. The primary objective of this interview was to gather insights into the approaches adopted by developers when engaging with municipalities in Denmark, as well as how private stakeholders communicate with citizens regarding their projects. Additionally, the interview sought to elucidate the timeline of PV development, including whether the initial step involves dialogue with the community or the municipality, and which stakeholders are involved in the process. Furthermore, it aimed to uncover the strategies employed by developers to garner support from citizens for their projects.

Charlotte Tølbøl Henckel- City Planner in Vordingborg Commune

The interview with Charlotte Tølbøl Henckel was conducted on May 8th via Microsoft Teams. Henckel was selected for the interview due to her role in the municipality of Vordingborg, where numerous environmental investments are taking place. Given the influx of solar companies investing in the surrounding land, Henckel's insights could offer valuable perspectives on the phenomenon. As someone responsible for ensuring citizen satisfaction in the area, she possesses insights from the perspective of the local community. The primary aim of this interview was to understand how municipalities handle the influx of private developers, the requisite stages for project approval, and the level of empowerment citizens derive from public meetings. Additionally, as a city planner, Henckel was expected to provide insights on how planners can mitigate delays in the development of PV solar parks, offering a private perspective on potential strategies.

Kristian Borch- Ph.D. in biochemistry, MSc in mediation and conflict management, and holds a Graduate Diploma in BA (Organization and Management)

Personal communication with Kristian Borch, an expert in social acceptance of renewables and foresight, was conducted multiple times during the creation of this master project. His insights were invaluable for understanding community acceptance and resistance toward renewable energy power plants. The intended outcome of these communications was to gain insights into the creation of local values and citizens' involvement in Danish society.

3.2.4 Research design

Figure 11, which presents the research design, shows how the study was organized using the methodological principles covered in this chapter. An iterative technique is used to construct the design, allowing for adaption to new discoveries made along the route. By responding to the sub-questions in the prescribed sequence, the master project adheres to the final study design's structure. The previous sections *3.2.1 Horizontal Scanning*, *3.2.2 Document Analysis*, and 3.2.3 Interview provide further details on the preferred techniques and their applications.

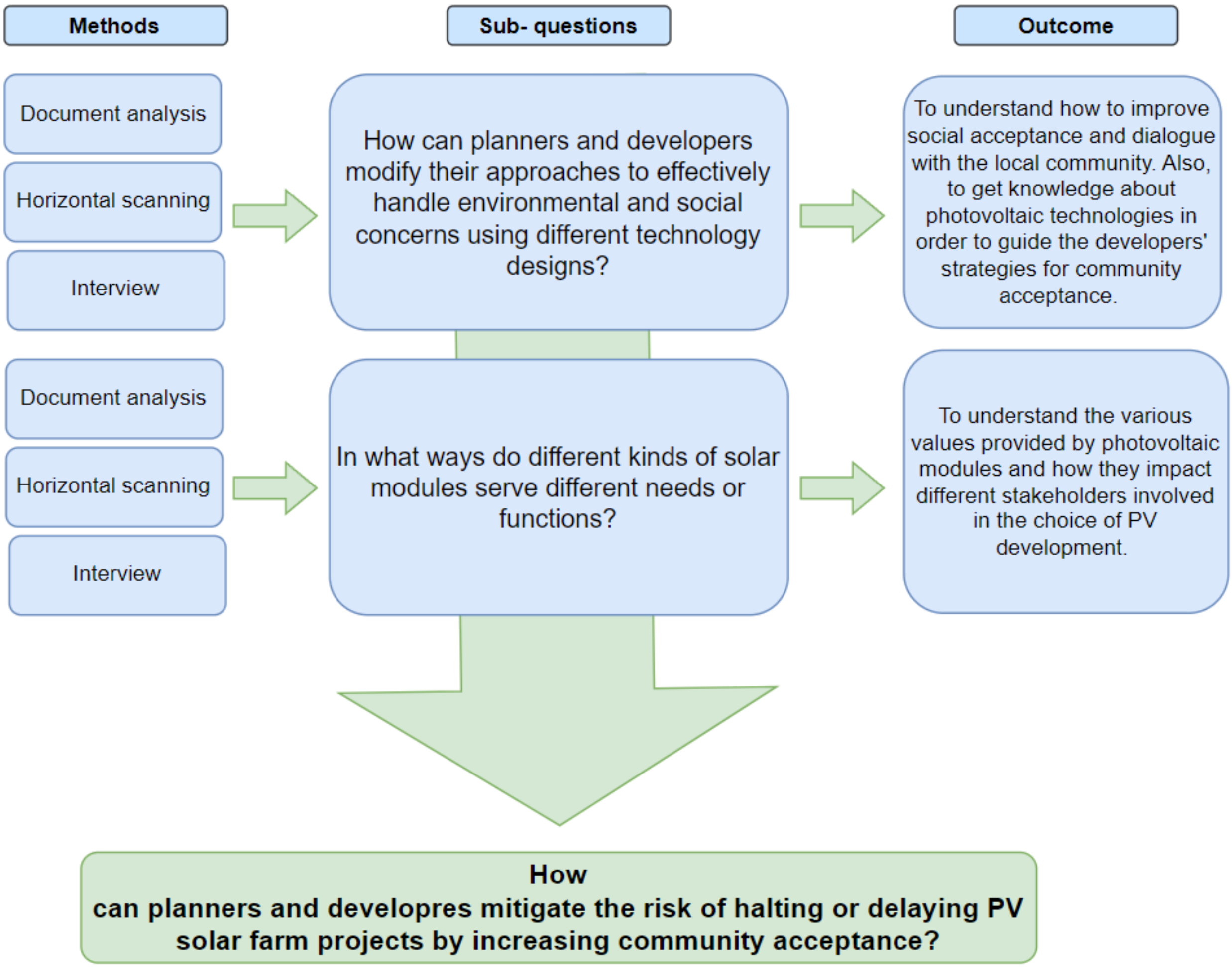

Figure 11- Research design

4. Discussion and Results

In the article titled "Municipal Energy System Modeling: A Practical Comparison of Optimization and Simulation Approaches," the author emphasizes the significant energy consumption stemming from individual heating systems (Johannsen, 2023). With population numbers on the rise and forecasts indicating a considerable increase by 2050, it's crucial to focus on local planning and improve municipal strategies to cut down energy use in households (Lutz et al., 2013). Furthermore, with the 2030 energy targets and new laws aiming for zero greenhouse gas emissions, nations worldwide are striving to achieve these ambitious goals (Wiatros-Motyka et al., 2024).

This chapter includes a stakeholder analysis aimed at creating a stakeholder map and describing the stakeholders involved in the PV development process, their interests, importance, and relationships with other actors. Additionally, two business models will be presented: one from the perspective of planners and authorities, and another from the perspective of private developers. Both business models seek to improve the planning process of photovoltaic power plant development and mitigate project cancellations or delays. Finally, the analysis will conclude with a scorecard comparing three types of photovoltaics, providing the local community with alternative options and greater freedom of choice.

4.1 Stakeholder analysis

To make a sufficient analysis of PV farm development, a stakeholder analysis has to be conducted. It will show who is involved in the process of solar farm investment as well as who has the power of the decision-making process. Moreover, the stakeholder map will be done to see what stakeholders have an impact on each other. The stakeholders will be categorized based on their interest and relationship to PV farm development in Denmark. They have been identified through interviews and document analysis.

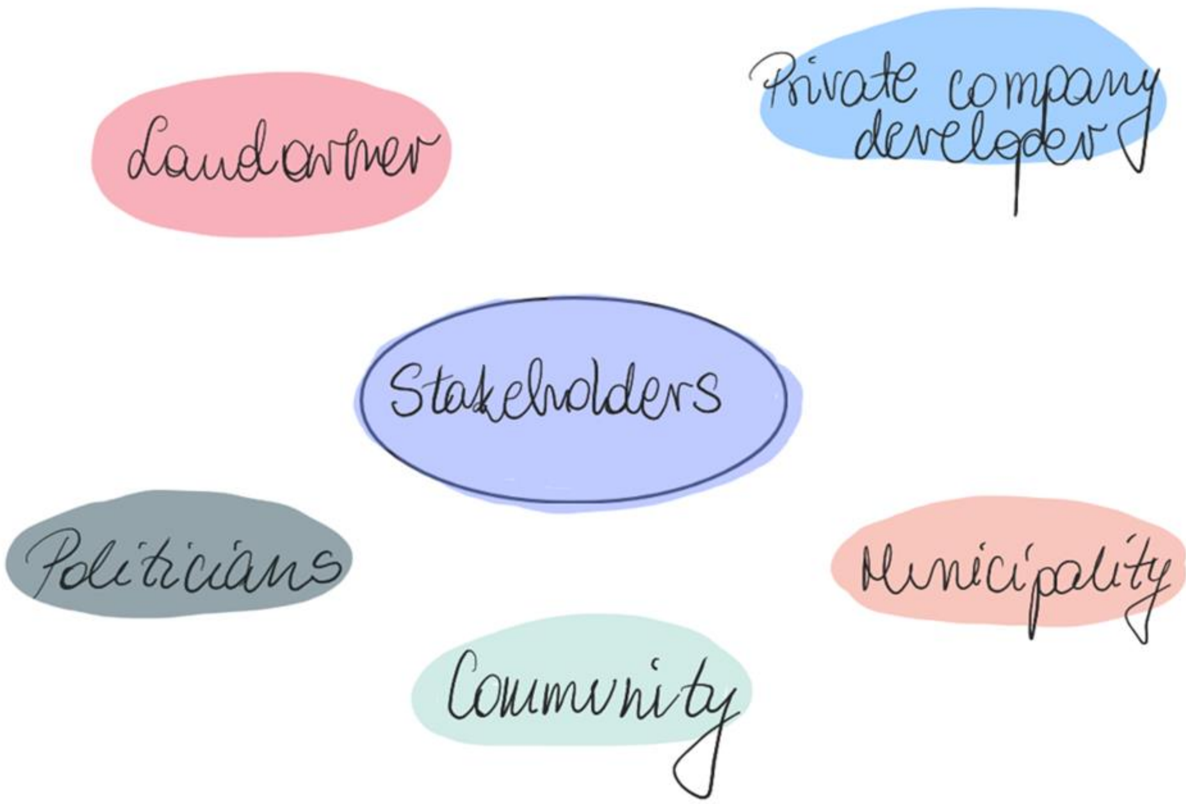

Figure 12- Stakeholder map of the actors involved in the PV development.

In the development of photovoltaic farms, five main stakeholders have been identified as having the greatest interest and resources. The first stakeholder to be examined is the private company.

Private company- developer

Private companies play a crucial role in the planning process of photovoltaic farms, possessing the most significant resources and standing to benefit the most from these investments. Developers are responsible for creating the plans and technical features that will be implemented in PV developments (Englund- Personal Communication, 2024). In an interview conducted with S. Englund, it was revealed that private developers either compete with other companies to win project initiatives in municipalities or independently approach landowners to gain community approval before submitting development requests to the municipality. He noted that private developers typically engage with residents in the areas of interest for development. There are two primary scenarios: residents living directly in the development area, who are directly affected, and those living nearby, who are secondarily affected. In the first scenario, representatives of private companies must engage with residents more intensively, offering to buy their houses or establishing mutually beneficial agreements to gain project acceptance. In the second scenario, representatives involve nearby residents collectively, as companies often lack the time and resources to engage with everyone individually (Englund- Personal Communication, 2024). After discussions with citizens, the next step in the development process is submitting a request to the municipality. The municipality then engages with politicians and the local community, presenting the project in detail. Following discussions, politicians decide whether to approve the project. Englund admitted that private developers often succeed in gaining project approval, especially when they have established connections. Private companies must also secure investors for their projects, ensuring that their plans, grid connections, and overall environmental impact are appealing to potential investors. Therefore, private companies have a significant amount of work to do, and their approach is critical. From an interview with Charlotte Henckel, it was concluded that private developers should approach communities with a deep understanding of the local area, offering more than just financial incentives. In a highly competitive environment, developers need to add additional value to their projects to stand out (Henckel- Personal Communication, 2024).

Landowner

Landowners are pivotal stakeholders in the stakeholder map as they own the areas of interest. For them, PV development represents a direct economic interest. Private companies approach landowners to discuss the terms of development. Depending on the situation, landowners may be offered compensation to lease their land. If their buildings are included in the development area, developers must provide compensation for demolishing the structures and relocating residents. During initial negotiations, landowners have the opportunity to establish conditions that must be met by the company. These negotiations are often challenging as both sides seek to achieve their desired outcomes (Englund- Personal Communication, 2024). Given that the area of interest is typically large, there are often multiple landowners involved. As C. Henckel mentioned, each municipality in Denmark has a master plan that designates areas suitable for renewable energy development. Therefore, landowners may anticipate being approached by private companies at some point, but the terms of development can vary depending on the company (Henckel- Personal Communication, 2024).

Municipality- planners

From the interviews, it is evident that the municipality serves as a mediator between private developers, citizens, and politicians in the process of photovoltaic farm development. A city planner involved in municipal decisions explained that municipalities organize multiple meetings regarding any proposed development within their jurisdiction (Henckel- Personal Communication, 2024). Firstly, all municipalities in Denmark have building master plans that designate areas suitable for renewable energy projects. When a private company approaches the municipality, planners begin arranging local hearings. A representative from the private company presents the project, and citizens can then ask questions, raise concerns, or voice opinions. Citizens are also permitted to submit comments on the new investment to public authorities. According to Henckel, all comments are carefully reviewed and considered. If there are recurring opinions, the municipality may adjust the project to align more closely with citizens' preferences. Subsequently, one or more hearings are held within the municipality, depending on the level of resistance or the choice of the best project for the municipality. Citizens wield significant decision-making power, although there have been no instances of citizens boycotting a project (Henckel- Personal Communication, 2024).

Community

The community holds the lowest stake but significant interest in the development of photovoltaic farms. Large-scale PV projects directly or indirectly impact all residents living in the development area. As previously mentioned, municipalities conduct numerous hearings and gatherings to provide citizens with opportunities to understand and comment on new developments within the commune. Citizens are encouraged to actively participate in these meetings, alongside representatives from private companies and public authorities. They can voice their opinions on the developments and submit them to the authorities for consideration. All comments are carefully read within a specific timeline, allowing citizens to express their opinions until a given deadline. If there is dissatisfaction or specific requests regarding a project, citizens are encouraged to emphasize these points within the given timeframe. As mentioned by the city planner, citizens wield significant decision-making power, as all comments are meticulously analyzed and discussed by planners and authorities. In summary, citizens are empowered by the municipality to have a greater influence on decisions made within the municipality (Henckel- Personal Communication, 2024).

Politicians

Politicians hold the greatest decision-making power as they are the ones who ultimately accept or reject projects within municipalities. They carefully weigh the advantages and disadvantages of each project and assess whether the benefits offered by private developers adequately meet the needs of citizens. Local authorities consist of individuals from the municipality who are not necessarily professional politicians but are dedicated to ensuring a better future for the local community. Therefore, politicians play a crucial role in determining the fate of projects within municipalities, considering both the interests of citizens and the overall well-being of the community (Henckel- Personal Communication, 2024).

In summary, the stakeholder analysis theory has enabled the creation of a stakeholder map and facilitated the analysis of the actors involved in the development process of photovoltaic power plants. This approach has provided insights into the influence each stakeholder has on other actors and has helped identify who holds decision-making power. Additionally, the theory has allowed for an examination of the resources held by stakeholders and the significance of their intentions in the development process.

4.2 Two business models

To address the first sub-question, “How can planners and developers modify their approaches to effectively handle environmental and social concerns using different technology designs?”, two business models will be developed. The first business model will focus on significant citizen engagement, promoting energy communities through planners, and implementing supportive legislation. The second business model will explore the developer's perspective, outlining what private companies can do to create greater acceptance for their projects.

4.2.1 I Business Model- Planner Perspective- Increase Public Engagement

The first business model will emphasize significant public engagement in the energy transition and the implementation of energy communities, alongside legislation that supports community-driven renewable energy development. Additionally, this master project will incorporate the qualitative findings of Rasmus Magni Johannsen, who examined “Tools and strategies for the local renewable energy transition”. He developed a modeling approach for local integrated energy systems and technical features from the perspective of energy planning. This research will integrate his findings with a social and psychological approach to local energy development (Johannsen, 2023).

4.2.1.1 Local Integrated Energy Systems

In the discourse outlined within the article, "Municipal Energy System Modeling: A Practical Comparison of Optimization and Simulation Approaches," the author initially directs attention toward the imperative of instituting long-term planning goals predicated upon strategic foresight. Notably, it is observed that certain municipalities exhibit a propensity towards compartmentalized energy development initiatives, wherein efforts are concentrated on reducing CO_2 emissions or curbing energy consumption within specific sectors. Such tendencies, while perhaps expedient for short-term objectives or politically motivated initiatives aimed at garnering public support, often neglect the broader imperative of comprehensive energy planning spanning entire municipal territories. This short-sighted approach is exemplified by instances where municipalities advocate for the adoption of renewable energy sources or the increase of electric vehicles without concomitant long-term strategic frameworks encompassing holistic energy planning solutions (Johannsen, 2023).

Moreover, the author underscores the complexity inherent in effectuating the transition from fossil fuels to renewable energy sources, emphasizing the multifaceted nature of this undertaking. Achieving this transition necessitates not only the careful calibration of diverse energy scenarios but also the seamless integration of disparate sectors within the energy landscape. Furthermore, the author contends that engendering widespread awareness and fostering informed decision-making among community members are indispensable prerequisites for effectuating meaningful change. In this regard, the author advocates for the utilization of localized awareness and knowledge as pivotal components within the arsenal of modeling tools employed for local energy planning initiatives (Johannsen, 2023).

4.2.1.2 Energy Strategy

Within the discourse of PhD, a pivotal emphasis was placed on the role of capacity and competence in shaping the efficacy of the energy strategy. This covered a wide range of factors, from the availability of staff and resources to the development of technical skills and knowledge unique to the energy sector. The energy plan's success depended on the careful management of material and human resources as well as a sophisticated comprehension of the technical nuances involved in energy management (Johannsen, 2023). In essence, the journey towards reshaping the municipal energy landscape necessitated a holistic approach that transcended mere policy formulation. It demanded a deep-seated commitment to fostering capacity, enhancing competence, and leveraging technological advancements to find a sustainable energy future that caters to the needs of both present and future generations.

The article titled "Designing Tools for Energy Systems Scenario Making in Municipal Energy Plans" delves into the multifaceted realm of energy planning within the municipal context. Central to the author's thesis is the assertion that while economic and environmental considerations are undeniably crucial, the social dimension serves as an equally pivotal pillar in the formulation of effective energy strategies. This recognition underscores a fundamental shift towards a more holistic approach that encapsulates the diverse needs and aspirations of local communities. The paper also explores the temporal dynamics that are inherent in energy planning, highlighting the significance of creating frameworks for decision-making that consider both immediate needs and long-term sustainability objectives. To clarify potential futures and guide strategic decisions, this dual focus calls for the use of sophisticated analytical tools and scenario-making methodologies. Additionally, it offers qualitative tools to improve energy planning at the local level (Johannsen, 2023).

Hence, in this master project, the focus shifts toward exploring qualitative measures that are challenging to calculate or represent graphically. This entails delving into aspects of energy planning that may not be easily captured through traditional quantitative methods or visualizations. From an economic and environmental standpoint, the business model also embraces social and psychological aspects. To encourage a broader perspective on renewable energy, which can offer more value to local communities, planners and local authorities should disseminate knowledge about energy planning and renewable resources. One effective tool to aid this process is the creation of energy communities.

4.2.1.3 Energy Community

In the discourse surrounding energy communities, a pivotal perspective emerges from the article titled "Energy communities: an overview of energy and social innovation," wherein the author underscores the emergence of energy communities as a burgeoning social movement. Contrary to conventional profit-driven ventures, the essence of energy communities lies not primarily in financial gain, but rather in the cultivation of social and environmental benefits for local communities. Delving deeper into the article, the author prominently accentuates the social services offered by energy communities over their economic counterparts. This emphasis suggests that beyond the tangible benefits derived from investing in photovoltaic systems, energy communities yield a spectrum of intangible advantages. These include fostering acceptance, increasing community involvement, empowering individuals, reinforcing positive social norms, enhancing awareness of the energy market, and capitalizing on renewable energy profits. Ultimately, energy communities serve as catalysts for social value and development, enriching the lives of citizens even those who may not be directly involved in the projects, all in the pursuit of the greater public good (Caramizaru et al., 2020). Community energy initiatives possess the remarkable capacity to empower individuals to partake in decision-making processes concerning renewable energy. This empowerment fosters greater citizen participation and control, reflecting the potential for profound social innovation inherent within these initiatives. Notably, the inclusivity of energy communities transcends financial barriers, ensuring that the benefits of decentralization extend equitably to all members of society, irrespective of their economic status or access to capital (Caramizaru et al., 2020). Research indicates that a combination of social capital, civic-minded behavior, environmental consciousness, and interpersonal trust serves as primary motivators for individuals to join energy cooperatives (Koirala et al., 2016) In conceptualizing energy communities, scholars such as Geels frame them as grassroots or niche innovations that navigate learning curves within socio-technical contexts (Geels, 2004). Additionally, these communities espouse a commitment to place and prioritize citizen involvement in both process and outcomes (Caramizaru et al., 2020). Such insights illuminate the multifaceted nature of energy communities and their potential to reshape social dynamics while advancing sustainable energy practices. As outlined in the article "Energy communities: an overview of energy and social innovation," energy communities offer a range of valuable services:

- Local Value: Energy communities contribute to the local area by reducing CO2 emissions, enhancing sustainability, promoting energy independence, potentially creating employment opportunities, and preventing the outflow of financial resources from the region.
- Decision-making and Democracy: Citizens within energy communities have local control over energy production and surplus distribution, facilitating democratic decision-making processes.
- Generating Financial Returns: Surpluses generated by energy communities can be reinvested in local activities, furthering economic development and sustainability initiatives.
- Empowerment and Education of Citizens: Energy communities empower citizens by enabling them to collaborate with municipalities and local authorities in combating climate change through collective action. This fosters a sense of civic engagement and environmental responsibility.
- Social Cohesion: Participation in energy communities builds trust among citizens and fosters a sense of belonging, strengthening social cohesion within the community (Caramizaru et al., 2020).

These benefits not only improve the quality of life for citizens but also stimulate awareness and enthusiasm for new initiatives. In essence, energy communities reflect a collective desire for self-sufficiency and community-driven progress, as citizens strive for greater independence from fossil fuels and centralized energy sources (Caramizaru et al., 2020).

Indeed, the concept of energy communities finds greater resonance in regions with a strong tradition of public sharing and community ownership, predominantly observed in Northern and Western Europe (Lissowska, 2013). Conversely, in Eastern Europe, where centrally-planned economies historically prevailed, there exists a prevalent skepticism and negative connotations regarding cooperation and trust. This disparity in perception may stem from deep-rooted socio-political factors, as highlighted by Lissowska, who suggests that distrust in energy communities within Eastern European countries can be attributed to the influence of national and local political institutions (Lissowska, 2013). Geels further accentuates the challenges that energy communities may encounter, irrespective of geographical location. These challenges include conflicts of interest, variations in local culture, deficiencies in democratic practices, and local opposition to renewable energy initiatives (Geels, 2004). Such obstacles underscore the complexities inherent in implementing community-led energy projects and the need for nuanced approaches to address diverse socio-political contexts.

4.2.1.4 Summary

This business model demonstrates how municipalities can promote the renewable energy transition and engage citizens with a new mindset toward energy development. It provides examples of how communities and planners can involve citizens in renewable energy projects. These initiatives are primary alternatives for spreading knowledge about available technologies and encouraging public participation in local projects. By implementing these proposals, planners can empower the local community, offering them real decision-making opportunities. Additionally, this approach allows the local community to gain a comprehensive understanding of the energy supply and demand in their region, making them more aware of energy prices and the developers' strategies. However, as mentioned earlier, energy communities may face resistance in some areas. Not all countries, particularly those in Eastern Europe, are open to new community initiatives. Therefore, this research will also develop a second business model, which will provide tools for developers on how to effectively approach local communities with significant levels of resistance.

4.2.2 II Business Model- Developers Approach- Higher Acceptance of Profitable Business Model

As shown by the stakeholder analysis, the creation of a new power plant involves five main stakeholders: developers, landowners, the community, politicians, and the municipality. This business model will primarily focus on three stakeholders with the most significant interest in PV development: private developers, landowners, and the community. In the stakeholder analysis, private developers have substantial interest and resources in developing photovoltaic solar farms. Additionally, PV companies are partly responsible for the project timeline and for maintaining dialogue with landowners and citizens (Henckel- Personal Communication, 2024). Therefore, the business model analysis will be conducted from the perspective of the private developer. This analysis will respect the timeline of photovoltaic development in Danish communities and will provide private companies with practical tools to enhance their effectiveness in engaging with local communities.

4.2.2.1 Public Acceptance

As Kristian Borch mentioned, no one wants to face judgment from others at the local shop (Borch- Personal Communication, 2024). This situation can arise when landowners and developers neglect to consider the local community's interests. Borch also observed that:

> *In many cases, the impact of technology on society is underestimated, especially the impact on those actors who are influenced by technological change but without perceived benefit* (Borch, 2018; Wüstenhagen et al., 2007).

As discussed in the problem analysis *2.6 Acceptance*, individuals seek to benefit from developments in their community, particularly when these developments are near their homes. Community acceptance involves both the local community and authorities and their specific attitudes towards a project. Research indicates that at the national level, most people are supportive of photovoltaics and renewable energy sources overall (Devine-Wright, 2004). However, according to interviews with S. Englund, and C. Henckel, there is significant resistance among local residents toward large-scale PV farms (Henckel Tølbøl Charlotte, 2024,Sonny Englund, 2024).

To reduce local resistance, PV companies need to adopt a different approach to engaging with the community. Additionally, landowners must consider their acceptance within the local community. Concerns raised by residents include the use of agricultural land for PV parks, which affects food production, the impact on local habitats and biodiversity, and their visual impact on the area. These factors negatively affect the well-being and quality of life in the region. In this scenario, developers must adopt a different approach to acquiring land. The current business model, which focuses solely on economic benefits, is no longer sufficient (Borch- Personal Communication, 2024).

Furthermore, companies that fail to consider values beyond economics are damaging their reputation (Borch- Personal Communication, 2024). From the interview with the city planner, it is apparent that citizens are more likely to accept a project when there is greater local engagement. She emphasized that people seek a clear understanding of the project and are provided with public hearings regarding proposed developments in their neighborhood. When the representative of a private company effectively communicates the project's goals, benefits, and drawbacks, people are more inclined to cooperate with the developer (Henckel Tølbøl Charlotte, 2024). Both C. Henckel and Borch highlighted that citizens want to derive benefits from a power plant that will impact their lives and area (Borch- Personal Communication, 2024; Henckel- Personal Communication, 2024). Additionally, C. Henckel argued that people are more likely to approve a project without significant obstacles when the developer offers something to the local community, not necessarily just in terms of money or cheaper energy. She provided an example where a local community may not readily accept a project, but they desperately want to support their local football team and lack the finances to build a proper football pitch. In such a case, if the developer were to engage more with the local community and understand their needs, they could make an attractive offer to the citizens. For instance, the developer could build the photovoltaic solar farm and financially support the construction of the local football pitch. From the interview, it can be concluded that people seek to derive benefits from PV parks not only from an economic perspective but also from psychological and sociological viewpoints (Henckel- Personal Communication, 2024). To gain citizens' approval, it's essential to offer the PV park more value than just economic benefits.

4.2.2.2 Dual- use of PVs

Dual-use or unconventional projects tend to be more attractive to people living around solar parks. Combining PV farms with biodiversity support makes the power plant more appealing to citizens. For instance, implementing Agro-PV allows landowners to harvest both the land and the sun simultaneously. By leasing the land to developers, landowners not only profit economically but also gain social acceptance from the local community. However, it's worth noting that not all private companies utilize innovative approaches when building large-scale solar farms.

Therefore, one private company stands out for its different approach—Better Energy. This company designs innovative solar parks that combine sun harvesting with biodiversity support. Better Energy doesn't just create wide gaps between rows and plant wild weeds; they develop zoning plans for the area that incorporate solar parks, lakes, bushes, wild grasses, and more (Better Energy, n.d.) As mentioned on their website, a solar power plant can provide not only economic benefits and clean energy but also:

"With careful research and planning, solar plant sites can help restore and conserve nature, increase biodiversity, and support healthy ecosystems." (Better Energy, n.d.)

This validates that large-scale solar parks can generate economic value while simultaneously supporting the environment. Furthermore, Better Energy has initiated a pilot project in Blangslev municipality, encompassing almost 70 hectares of photovoltaic energy power plant. This plant generates approximately 52.5 GWh yearly and incorporates seven additional elements to support biodiversity and ecosystems. One such element is "The fruit grove," where shrubs and berry-bearing trees have been planted to provide food for insects, birds, and small mammals. Another feature is located on the hill, designed to offer an overlook of the solar plant with stones and wildflowers that support cold-blooded animals. Additionally, in the central area of the power plant, the company removed the agricultural drainage layer to create a natural wet biotope. In the northern part of the power plant lies the forest garden and flower edge, featuring various plant species and providing habitats for numerous animal species. Furthermore, to create natural habitats for larger mammals, forests and grasslands were established in the central areas of the solar park. All of these aspects make the solar park unique and exceptional. Better Energy's project stands out for its commitment to environmental support, as it allocated a significant amount of land to benefit the environment instead of installing additional PV modules. In doing so, the company added considerably more value to its power plant. Not only did the ecological value increase significantly, but the social and psychological values also saw an improvement. Citizens are eager to support their local environment and enhance the value of their land for future generations (Better Energy, n.d.). There is an opportunity for companies to gain more acceptance among citizens, but this requires a change in approach. Private developers must broaden their perspective to recognize the various values in PV projects beyond just economic ones.

4.2.2.3 Having a choice

Therefore, people desire to have a choice, which aligns with the theory of Choice awareness. Private developers should provide genuine options when proposing any development. As C. Henckel argues, people want to feel that they have a real say in the decision-making process, essentially seeking procedural justice (Henckel- Personal Communication, 2024; Wüstenhagen et al., 2007). She provided another example where communities are given the opportunity to choose the location of a project that will occupy a significant area. In such cases, community involvement increases significantly as they compare and evaluate the merits of each location. Instead of focusing on the obstacles of one site, they concentrate on making the best decision for the community as a whole. Moreover, choice awareness asserts that individuals should have a genuine choice regarding the area in which they reside. People are more likely to accept a project when they feel empowered and their decision-making authority is respected (Henckel- Personal Communication, 2024).

From this perspective, developers should recognize that an essential aspect of an effective project is providing people with genuine choices. Private companies should attempt to offer various options when there is no possibility of choosing between two sites. These could include solar parks supporting biodiversity, integrating agriculture with energy production, or providing different types of photovoltaics, as further elaborated. These options must be transparent to ensure that people understand the topic and are aware of the alternatives available. Additionally, the community must trust the representatives of the private company to feel secure and perceive justice in the process (Henckel- Personal Communication, 2024). Offering choices will inevitably result in a longer and more complex development process for PV farms. As S. Englund points out, companies often lack the time or resources to involve all citizens or host numerous gatherings. However, this ultimately depends on the company's priorities—whether they prioritize economic benefits or embrace different values that solar parks can provide (Englund- Personal Communication, 2024).

4.2.2.4 Summary

To effectively engage citizens, private developers can offer different types of photovoltaic modules. In cases where ground-mounted modules face significant resistance, investing in more innovative solar panels becomes a viable option. Furthermore, if citizens prioritize having a greater positive impact on biodiversity and the environment, developers can explore options to combine solar panels with agriculture or biodiversity support initiatives. By integrating solar panels with these additional features, they can provide not only economic and environmental benefits but also social and psychological ones. To provide an overview of the technologies available on the market, this master project will present a scorecard and comparison of three types of photovoltaic modules, explaining their respective values and advantages.

4.3 Comparison of the 3 types of PV modules

This analysis will commence with a comparison of the three types of PV modules introduced in 2. Problem Analysis: ground-mounted, transparent, and vertical solar panels. This allows to answer the second sub-question: "In what ways do different kinds of solar modules serve different needs or functions?". While technical features will be outlined, the primary focus will be on the social benefits offered by each module type, as well as the services and values they generate. To enhance visualization, a scorecard will be presented.

Table 4- Scorecard of ground-mounted transparent, and vertical PV modules

	Ground-mounted	**Transparent**	**Vertical**
Technical features			
Life span	green	red	yellow
Available technology	green	red	yellow
Energy production	green	yellow	yellow
Economic values			
Cost of production	green	yellow	yellow
Cost of Maintenance	yellow	red	green
Dual use	red	green	yellow
Space occupied	red	green	yellow
Appealing for investors	green	red	yellow
Civil aspects			
Environmental impact	red	green	yellow
Knowledge	green	red	yellow
Visual impact	red	green	red

As mentioned in section *2.6 Acceptance*, the values provided by renewable energy can be categorized using the Value Framework (Wüstenhagen et al., 2007). This framework identifies four main values: economic, ecological, psychological, and sociological.

First, the ground-mounted PV panels will be examined.

Economical value:

From an economic standpoint, ground-mounted solar modules offer significant appeal. Their well-established technology, declining production costs, and superior efficiency make them highly appealing to investors seeking substantial returns. Moreover, their extended lifespan translates to a shorter payback period and prolonged benefits from the solar park. However, maintenance costs emerge as a notable economic disadvantage. Ground-mounted PV panels require regular cleaning due to dust accumulation, which reduces efficiency, and they are vulnerable to bird droppings. Despite this drawback, regular maintenance ensures optimal performance, with weekly cleaning recommended to mitigate efficiency losses (Mustafa et al., 2020). Overall, despite the associated maintenance expenses, the long-term economic benefits of ground-mounted PV modules outweigh these costs, making them a preferred choice for investors aiming to capitalize on renewable energy investments.

Ecological value:

From an ecological perspective, ground-mounted PV panels are rated as the least favorable option. Typically, they occupy up to 90% of the available area, impacting the soil due to their technical features. In the most common configuration, where rows are narrow and panels closely spaced, biodiversity support is severely limited. The shadows cast by the metal structures hinder plant growth and restrict sunlight access for insects, reducing ecological diversity. Additionally, integrating ground-mounted PV panels with other land uses proves challenging; innovative solutions like wider row gaps are necessary for multipurpose utilization, such as Agro-PV combining agriculture with solar panels. However, this compromise results in reduced energy generation.

Psychological value:

Ground-mounted solar panels are widely recognized in the market, with their familiarity among people. According to the article "Mapping value perspectives on wind power projects: The case of the Danish test center for large wind turbines," social value is associated with well-being, appreciation, and quality of life (Borch, 2018). It is described as civil aspects in Table 4, considering the combination of environmental impact, knowledge, and visual impact. Interviews reveal significant resistance toward large-scale ground-mounted solar farms, as they are perceived as negatively impacting the local community and visually altering the area. Englund noted that while people are generally supportive of renewable energy sources, they prefer not to have them in their immediate vicinity. However, there are exceptions. Englund cited a case where citizens unanimously accepted a PV development during a community gathering. They were environmentally conscious, recognized the area's suitability for renewable energy, sought benefits from energy generation, and perceived no negative impact on their well-being (Englund- Personal Communication, 2024).

Sociological value:

In considering sociological value, it's crucial to examine how local communities engage with technology, both its benefits and obstacles. Ground-mounted technology holds a prominent position in this regard, being widely recognized and actively promoted by various stakeholders such as the media, politicians, and local authorities as an effective means of harnessing solar energy. Private developers, driven by the desire to maximize returns on investment, often approach communities with proposals featuring ground-mounted PV modules. Henckel's argument underscores the significance of community gatherings preceding final decisions by politicians regarding such projects. However, the outcome of these gatherings is heavily influenced by the representatives of private companies. A city planner emphasized that clear communication during these gatherings is essential for community members to grasp the project's advantages and disadvantages, thereby increasing the likelihood of acceptance (Henckel- Personal

Communication, 2024). Additionally, S. Englund highlighted the critical role of time and resources in garnering community support. In an ideal scenario with ample time and resources, the process of engaging with local communities and facilitating gatherings would be more extensive. However, practical constraints, such as tight application timelines and limited resources, often lead to inadequate outreach and, consequently, heightened resistance among community members (Englund- Personal Communication, 2024).

To sum up, the scorecard and value provided by ground-mounted solar panels is: The ratio between green-yellow-red result:

6-1-4

Ground-mounted PV modules are renowned for their efficiency and profit potential, making them a top choice for investors. However, their environmental and human health impacts are equally significant. Despite achieving high green ratings for their efficiency, they also score poorly in terms of their adverse effects on the environment and well-being, earning high red ratings.

Next, transparent photovoltaics will be examined.

Economical value:

The lesser-known and less widespread technology of transparent photovoltaics comes with higher costs and more complex maintenance requirements. Unlike opaque modules, the lifespan of transparent modules is directly tied to production costs. Higher production costs yield longer lifespans, while cheaper materials result in shorter lifespans, affecting affordability. Transparent photovoltaic technology differs significantly from opaque modules, contributing to its limited availability in the market. Additionally, transparent modules exhibit lower efficiency compared to opaque ones, resulting in decreased energy production. This reduced output translates to longer payback periods, further diminishing their appeal to investors. Overall, these factors contribute to the lesser attractiveness of transparent photovoltaics for investment purposes.

Ecological value:

Transparent photovoltaics offer numerous environmental benefits, presenting an eco-friendly alternative to traditional solar technologies. Their integration into glass objects eliminates the need for additional space and prevents ground contamination. Unlike conventional solar panels, transparent modules seamlessly blend into their surroundings, preserving the natural landscape and minimizing visual disruption for people and wildlife. Furthermore, transparent photovoltaics were specifically designed for dual use, allowing for versatile applications. One such application involves integrating them into skyscrapers, leveraging the extensive glass surfaces of these buildings to generate renewable energy. This approach has the potential to cover up to 50% of a building's energy usage, significantly reducing reliance on non-renewable sources (Pillai et al., 2022). Another promising application lies in greenhouses, where space efficiency is paramount. By combining transparent PV technology with greenhouse structures, it's possible to simultaneously support plant growth and generate clean energy. Research indicates that transparent modules can be engineered to have minimal impact on plant development, ensuring optimal conditions for cultivation while harnessing solar energy effectively (Emmott et al., 2015).

Psychological value:

Transparent photovoltaics, while seemingly inconspicuous, have the potential to significantly impact people's lives and well-being positively. By integrating vertical modules onto windows, buildings can generate electricity, thereby reducing energy costs and improving quality of life. Although perfecting colorless photovoltaics is complex, the slight shadow they cast can create a comfortable work environment, particularly beneficial for those who spend extended periods working on computers. However, a notable drawback is their status as a niche technology. Limited awareness about transparent photovoltaics means that many people are unaware of their existence and potential benefits. In the context of greenhouses, concerns may arise regarding their impact on plant growth. Notwithstanding these difficulties, transparent photovoltaics are a viable option for producing sustainable energy that could improve agricultural and urban infrastructure.

Sociological value:

According to the article "Semitransparent Building-Integrated Photovoltaic: Review on Energy Performance, Challenges, and Future Potential," transparent photovoltaics face numerous obstacles. Chief among these is a lack of promotion; without widespread dissemination of knowledge about the technology, obtaining approval for its installation becomes unlikely. Furthermore, weak energy policies hinder development, imposing limitations on the market. Additionally, a shortage of personnel with expertise in this field means there are few individuals available to transfer knowledge and advocate for the technology. Without advocates to present the new technology, community gatherings to discuss its potential are less likely to occur. These challenges underscore the need for concerted efforts to overcome barriers to the adoption of transparent photovoltaics (Joseph et al., 2019).

The score is:

4- 2- 5

Transparent photovoltaics offer a promising solution for areas with limited space availability, presenting an environmentally friendly option that does not encroach upon the ground or disrupt ecological balance. However, despite their potential benefits, the challenges associated with transparent photovoltaics overshadow their positive aspects. Limitations in technology, market accessibility, and knowledge dissemination hinder their appeal to investors. Consequently, while transparent photovoltaics boast numerous advantages, they currently rank poorly in terms of overall viability and attractiveness for investment.

The last type to be examined will be vertical photovoltaics.

Economical value:

Vertical solar panels are classified as medium in terms of technology availability; they are less available than ground-mounted PV panels, but the difference is not significant due to their similar construction. Their lifespan is also comparable to that of basic PV modules. Energy production from vertical solar panels depends on the location of the power plant. The article "Vertically mounted bifacial photovoltaic modules: A global analysis" shows that vertical photovoltaics can be 5-20% more efficient than ground-mounted ones in high latitudes above 50°N. Consequently, in countries closer to the equator, such as China, India, Australia, and Spain, vertical solar panels are less attractive (Guo et al., 2013). The production cost of vertical PV modules is the same or higher than that of ground-mounted modules because bifacial vertical modules have two layers for absorbing sunlight. However, vertical PV modules offer significant maintenance advantages. Positioned perfectly vertically, they do not accumulate dust or other particles on their surfaces. Additionally, in snowy regions, vertical panels prevent snow and freezing rain from sticking to the surfaces, making them an appealing option (Guo et al., 2013).

Ecological value:

Vertical photovoltaic modules have a moderate environmental impact. Although they occupy less area than traditional ground-mounted modules, they still affect the surface and natural habitats. However, they can be utilized as fences or highway barriers, making them versatile. Their vertical positioning also makes them easier to integrate with agriculture, supporting biodiversity by allowing larger gaps between rows (Guo et al., 2013). Despite these benefits, they are less suitable for dual-use applications compared to transparent modules.

Psychological value:

Vertical photovoltaics, like transparent ones, are not as well known as ground-mounted systems. This lack of awareness leads to a less favorable attitude toward their implementation. Authorities do not promote this technology extensively, and developers rarely offer it to municipalities. Although vertical panels occupy less space, their metal and glass components remain visible, contributing to visual impact. According to the scorecard, the visual impact of vertical modules is comparable to that of ground-mounted panels. However, if vertical panels were more widely implemented, their impact on societal well-being could be less significant.

Sociological value:

As mentioned above, vertical photovoltaics are not well-known in the market, and the technology is not widespread. This presents obstacles to the adoption of these unconventional PV modules. There is a lack of specialists who can promote this new type to authorities. Additionally, investors are hesitant about new technologies, preferring those with the shortest payback periods. The uncertainty surrounding the payback period of new PV types, due to limited research and implementation, further deters investment (Englund-Personal Communication, 2024). Without promotion and widespread implementation, it is challenging to convince people of the real benefits of new technologies. Moreover, citizens are not typically offered a choice of different technologies; private developers usually offer only the primary and most efficient types of photovoltaics.

The score is:

1- 9- 1

Vertical photovoltaics are considered the most moderate type of solar panels, causing minimal environmental and psychological harm. A key factor for this type of module is its dependence on location. If vertical photovoltaics were more widely implemented in countries above 50° latitude, they could be a strong competitor to ground-mounted systems.

This comparison highlights the advantages and disadvantages of different photovoltaic modules. It reveals values that may not be immediately apparent and, through the use of a scorecard, shows which type of photovoltaics is most suitable for various circumstances. It also indicates which types should be promoted more to achieve broader recognition. The goal of this comparison is to showcase the strengths and weaknesses of different PV types and demonstrate that ground-mounted photovoltaics is not the only viable solution for harvesting solar energy.

4.4 Summary

This chapter has addressed both sub-questions, which focus on how planners and developers can modify their approaches to effectively handle environmental and social concerns using different technology designs, and also what services are provided by different PV technologies. It has highlighted two business models in which the community's role is underestimated. The analysis provides a clear overview of what municipalities, planners, and private companies can do to garner greater acceptance for large-scale photovoltaic power plants among citizens.

Moreover, it delves into different types of solar panels, which can empower and offer greater choice to the local population. Planners play a crucial role in providing knowledge and promoting renewable energy by creating safe communities, such as energy communities, and disseminating information among developers on how to address resistance towards large solar projects.

5. Conclusion

The conclusion will address both sub-research questions: “How can planners and developers modify their approaches to effectively handle environmental and social concerns and lower the probability of project delays?” and "In what ways do different kinds of solar modules serve different needs or functions?". It will also examine the initial findings of this project to answer the main research question: "How can planners and developers mitigate the risk of halting or delaying PV solar farm projects by increasing community acceptance?"

This master project focuses on the delay and cancellation of large-scale PV projects and the debate over prioritizing economic benefits versus other values provided by renewable energy sources. In the context of an environmental crisis and the increasing emphasis on energy independence, supporting renewable energy power plants is crucial.

Firstly, it reviews why citizens are often dissatisfied with photovoltaic power plants. Interviews and document analysis reveal that citizens feel neglected in technological investments in their region (Devine-Wright, 2004). Negotiations for renewable investments typically occur between private developers and landowners, often overlooking social and psychological aspects in favor of profit maximization. As a result, residents feel a disproportionate imbalance between decision-making power and procedural justice (Wüstenhagen et al., 2007). The process is frequently unclear, leading to concerns about whether their community will benefit from the investment.

Furthermore, interviews and an analysis of Choice awareness indicate that people strongly desire to make meaningful decisions regarding their well-being. This raises an important question: should the focus remain on profit maximization at the expense of citizen satisfaction, or should the development of solar farms adopt a new approach that addresses different needs and functions?

Based on these findings, the analysis of two business models and the comparison of three types of photovoltaic modules were key factors in understanding how planners and developers can prevent resistance to PV energy plants among citizens. The first business model emphasizes empowerment and engagement and pushes for the formation of energy communities. This entails giving locals a chance to participate in decision-making and express their concerns at an early stage of the planning process. To foster confidence and eliminate false information, projects must be transparent and communicate their benefits and impacts in a clear and concise manner. Solutions for solar electricity can also be made more relevant and widely accepted by customizing them to fit the unique requirements of various communities. An effective business model that increases community acceptance should include:

- Engagement and Empowerment: Allowing local communities to express their concerns and desires early in the planning process, and giving them control over decision-making. This builds trust and fosters a sense of belonging, engagement, and responsibility.
- Transparency and Acknowledgment: Providing easily comprehensible information about the advantages and possible effects of PV projects to foster trust and minimize misinformation.
- Tailored Solutions: Adapting solar power options to the unique requirements and environments of various communities, increasing their applicability and significance.

The second business model addresses the challenges of PV development without creating an energy community, where the private developer is the leading stakeholder. This concept proposes teaching locals about the advantages of renewable energy, promoting biodiversity within solar parks, and holding public forums to explain projects and solicit comments from the community. It's critical to keep up a conversation about community issues and provide financing for local projects. Achieving a balance between profit and well-being requires providing options and alternatives, combining solar energy generation with environmental preservation, and taking into account the effects on society, the environment, and the economy. To minimize the probability of delays or cancellations, the developer's strategy should involve:

- Engagement and Acknowledgment: Hosting public meetings to explain the project and gather feedback, educating on renewable energy benefits, enhancing biodiversity within the solar park, and involving citizens in the decision-making process.
- Transparency and Involvement: Clearly communicating benefits and impacts, maintaining ongoing dialogue to address concerns, understanding community needs, and funding local initiatives.
- Choice and Justice: Offering choices and alternatives, integrating solar production with environmental conservation, proposing dual-use projects, and addressing social, environmental, and economic impacts.

In both business models, engaging and empowering the local community is crucial. Involving citizens in projects within their region is essential, as they have a strong sense of belonging. Greater involvement in the development process makes them more likely to accept the project in their neighborhood. The second business model emphasizes the importance of choice. This research provides private developers with an overview of the three most popular photovoltaic technologies currently on the market. The comparison considers economic, environmental, sociological, and psychological values, with scores categorized as green, yellow, and red- corresponding to good, moderate, and bad rates:

- Ground-mounted PV: 6-1-4
- Transparent PV: 4-2-5
- Vertical PV: 1-9-1

Ground-mounted PV modules are still considered the most efficient and attractive for investors. However, they also have high scores for negative environmental impact, visual disruption, and effects on well-being. Additionally, they are not easily combined with other uses, such as agri-voltaics or biodiversity support. Transparent PV modules offer significant potential for dual use. They do not require additional space, are almost invisible to the human eye, and can be installed on the roofs of greenhouses, minimizing visual impact. Despite being less efficient and more expensive than opaque modules, and sometimes meeting resistance when combined with food production, they offer a less intrusive alternative. Vertical PV modules have fewer pronounced strengths and weaknesses. Their scores suggest they are moderate in terms of economic, environmental, and social impact. Vertical PV panels may be a viable alternative for European countries with less sunlight compared to equatorial regions, offering a balance between maximizing monetary profit and maintaining well-being.

When comparing these modules, it is important to optimize their use based on location. If the site has ample land that is not suitable for agriculture and has no nearby residents, ground-mounted modules are the best option. They are the most efficient, and developers are familiar with the technology. However, in populated regions where residents are likely to oppose the project, alternative technologies should be considered. Transparent PV modules, although less profitable and appealing to investors, can be suitable for smaller investments. For instance, in regions focused on food production with limited space for solar power plants, transparent PV modules can be installed in greenhouses. Vertical modules can also be used in combination with biodiversity support. It is hard to choose the best type of photovoltaic module, the choice of photovoltaic technology should depend on the specific conditions of the location and the preference of the local community.

5.1 Summary

This research is both qualitative and quantitative, encompassing not only economic and technical aspects but also psychological and sociological dimensions. Unlike quantitative research, which relies on mathematical calculations to determine the efficiency of photovoltaic modules or their economic value in the market, this master project takes a strategic assessment approach. The goal is to present a broader understanding of photovoltaic modules and their impact on local communities. The project aims to highlight the diverse factors influencing the acceptance and implementation of PV solar farms.

It is clear from a thorough examination of the records and interviews that community involvement is frequently inadequate. People express worry about the absence of openness, believing that the investments may not benefit their communities. There is a great demand for methods that go beyond profit maximization, which is reflected in the desire for meaningful engagement in decision-making processes. By examining the likely reasons behind delays or cancellations of PV projects, this study aimed to address these concerns. In the absence of case studies, obstacles, and public dissatisfaction were scrutinized through interviews and document analysis. Presently, there is a pressing demand for investment in renewable energy to support environmental restoration and meet energy targets. However, it's crucial for solar power plants to maintain a positive reputation among the populace and for flexible technology applications to proliferate globally. The case of Better Energy exemplifies how PV modules can integrate four key values into one site, serving various stakeholders such as the community, landowner, developer, and local authorities. Through this study, planners and developers can leverage the insights provided to enhance the acceptance, speed, and efficiency of PV solar power plant development

This demonstrates that planners and developers should collaborate, as they have different approaches but the same goal. By integrating the knowledge and local perspective of planners with the stakes held by developers, photovoltaic developments can achieve a new level of effectiveness. This collaboration ensures both profit maximization and community acceptance are fulfilled.

To sum up, this study offers new strategies and resources to private developers and planners to shorten the time it takes to build PV farms. It is possible for developers to promote higher acceptance and more seamless deployment of solar projects by taking into account the broader consequences of photovoltaic technology and giving community participation and customized solutions a priority. The strategic, qualitative evaluation emphasizes how crucial it is to incorporate sociological, psychological, technological, and economic aspects while developing renewable energy projects.

6. Limitations

While this research contributes valuable insights, it is essential to acknowledge its limitations. Being qualitative in nature, it relies on subjective human opinions, lacking complete objectivity. Moreover, local cultural, economic, and environmental factors can significantly shape the effectiveness of proposed strategies, rendering a universal approach impractical. The project's reliance on general trends and theoretical frameworks may not capture the nuances of diverse global contexts, potentially leading to misalignment with specific audience needs. Additionally, the examination of PV technologies was cursory, lacking detailed scrutiny. Rapid changes in technology and regulations within the renewable energy market may render certain project components outdated or less relevant over time, with the project possibly struggling to adapt quickly. Limited case studies and interviews may skew recommendations and conclusions, failing to represent the full spectrum of stakeholder perspectives adequately. Moreover, logistical constraints, such as interview refusals from key stakeholders like Better Energy, can hinder data collection and analysis. Future research avenues could explore different photovoltaic technologies and strategies for increasing their visibility. Furthermore, a deeper dive into stakeholder relations and more comprehensive interviews with involved actors could enrich understanding and inform more robust recommendations.

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6. Appendix

Interview with the city planner in Vordningborg Kommune- *Charlotte Tølbøl Henckel*

Guidance to the interview:

1. Can you introduce yourself and tell me what is your role in the Vordingborg commune?

2. Can you tell me in which project you were involved or are you involved (in an aspect of renewable energy)

3. Do you have any strategies when the PV developer approaches your community?

4. Are there any obligations for developers before commencing the planning process?

5. What is the citizen involvement throughout the planning stages?

6. What is the citizens' influence in the decision-making process concerning the acceptance of PV projects?

7. Is there high resistance to PV projects in your community?

8. Can you tell me what are the stakeholders engaged in the planning process, concerning PV development?

9. What are your main drivers when choosing the best PV project (while having multiple)

10. Do you think there would be more diverse choices for example combining agriculture with PV farms, or investing in vertical or transparent PV modules? There would be greater acceptance among the citizens.

11. Can you give your suggestion on what planners or developers could do to mitigate the delay of PV projects?

12. "How can planners mitigate the risk of halting or delaying PV solar farm projects?"

Interview with the Land Development Manager at GreenGO Energy- *Sonny Englund*

Guidance to the interview

1. Can you introduce yourself and tell me what is your role in Green Go Energy?

2. In which projects you were involved in?

3. Can you tell me the specific criteria or methods used to examine the land for suitability for solar energy projects? Are there any key factors or indicators we prioritize during this assessment process?

4. How do we typically initiate contact with landowners for potential project sites? Are there any strategies or approaches that are particularly effective in gaining landowner interest and cooperation?

5. Regarding the investigation of community engagement, what factors or considerations are involved in making this determination? How do communities influence a project approach or planning?

6. Do we have the procedure to contact the municipality and initiate dialogue with citizens?

7. When organizing citizen gatherings for a project, what objectives or outcomes do we hope to achieve? How do we ensure meaningful participation and engagement from residents?

8. How do we assess whether a project should prioritize basic energy production or incorporate biodiversity considerations? Are there specific environmental impact assessments or guidelines you follow in this regard?

9. Examples of specific initiatives or programs we've implemented in past projects. How do we measure the impact of these efforts on the local area? Are there any differences between different municipalities?

10. Can you tell me common examples of restrictions in land use or zoning regulations that we encounter? How do we navigate these challenges while still achieving project goals?

11. In what ways do we actively involve local stakeholders and community members in the restoration and maintenance of natural areas associated with PV projects? Are there any notable examples of successful community engagement?

12. Are there any plans or considerations for integrating new technologies such as vertical PV panels or transparent panels into your future projects? How do we assess the feasibility and effectiveness of adopting these technologies compared to more traditional solar panel designs?