1. Introduction and Problem Statement

The rapid growth of the solar photovoltaic (PV) industry has brought forth an unprecedented demand for renewable energy sources, with solar panels being widely deployed across the globe. However, as the number of solar panels and thus solar waste increases, so does the need for sustainable end-of-life management and recycling strategies (Haegel et al., 2017). Reducing solar panel waste is essential to mitigate the environmental impacts of the vast amounts of electronic waste generated by decommissioned panels and to recover valuable materials that can be reused in the manufacturing process (Xu et. al., 2018). Currently, solar panel recycling practices vary widely, with some countries implementing dedicated recycling facilities (Frischknecht et al., 2016), while others lack proper infrastructure or guidelines to address the issue.

However, while many academics, experts, and our challenge givers BayernLB are addressing the issue of solar panels recycling, one question persistently remained unanswered: When is it best to recycle solar panels? According to our research, solar panels have a degradation rate of approximately 0.5% per year. This accumulates 90% efficiency even after 20 years and 75% efficiency after 50 years (Aboagye et. al., 2021). The research further revealed that many PV operators in Germany still discard their solar panels after 20 years of use despite their relatively high level of performance.

Through our analysis, we were able to identify the reason behind it. It seems that the current regulatory framework, especially the Renewable Energy Act (Erneubare-Energie-Gesetz EEG) is considered a major obstacle for the prolonged use of panels (Bundesministeriums der Justiz & Bundesamts für Justiz, 2023). The EEG provides generous support to promote the use of solar panels and promote the use of these panels in the grid. However, the subsidy program expires after 20 years, leaving PV operators with very limited options. After the end of the funding period, PV operators can either sell their excess electricity at significantly lower prices on the open market or continue selling to the local power provider, but at a reduced rate. Alternatively, they can choose to disconnect from the grid altogether, which is an impractical option for many operators. These circumstances create a financial disincentive for operators to keep their panels beyond the EEG funding period, resulting in premature disposal and contributing to the growing problem of solar waste.

The disposal of functional solar panels leads to unnecessary environmental impact and represents a loss of valuable resources and potential revenue for PV operators. Thus, the research question we address in our challenge is:

"How can PV operators be incentivized to continue using their panels beyond the EEG funding period and maximize their financial returns while minimizing environmental harm?"

With this research question, this paper aims to examine the existing policies involved in solar panel recycling - more specifically the Renewable Energy Act of Germany (Erneubare-Energie-Gesetz) - and discuss the challenges and opportunities within the field. Furthermore, it will provide strategies for PV operators to be incentivized to continue using their panels beyond the EEG funding period. By exploring these aspects, the paper will contribute to a better understanding of the EEG about solar panels, how it affects solar panel waste and propose potential pathways to advance this critical aspect of the PV industry's lifecycle and thus pave the way for profitable, environmentally sustainable and sustainable solar projects.

2. Methodology

From the beginning of EuroTeQ, our team became cognizant of the Solar Panel Waste Challenge. Thus, in our research project, we employed a multi-faceted approach to comprehensively address the research question of incentivizing PV operators to continue using their panels beyond the EEG funding period.

We first conducted a thorough review of existing literature, academic research, industry reports, and policy documents related to solar panel lifespan, EEG regulations, renewable energy markets, and incentive mechanisms. This literature review helped identify the gap of solar panel prolonging in existing research, establish a solid foundation of knowledge and understanding of the solar panel industry, and provided valuable insights into potential solutions. The data we used were collected through interviews and case studies involving PV operators, energy experts, and relevant stakeholders. These interactions provided valuable qualitative and quantitative information regarding the challenges faced by PV operators, their perspectives on solar panel lifespan, the impact of EEG regulations, and potential strategies to incentivize panel retention.

3. Final Product/concept

3.1 EEG Law

EEG - the Renewable Energy Sources Act or German: Erneubare Energie Gesetz. The EEG law in Germany is a renewable energy law that promotes the generation of electricity from renewable sources, including solar. It introduces a feed-in tariff system that guarantees fixed payments to renewable energy producers for 20 years (Wittenberg & Matthies, 2016). Under the Renewable Energy Sources Act, owners of solar installations can benefit from a guaranteed payment for the electricity they generate and feed into the grid. The subsidy ends after 20 years, and then solar system owners must sell their electricity at a relatively lower price or pay additional fees to stay connected to the grid.

3.2 Promoting Smart meters

Smart meters are digital devices that measure electricity consumption in real-time and send the data to the utility (Bloch et. al., 2019). Households can access this information through a smartphone app or display in their home that shows them how much energy they are using and how much it is costing them. They can also see how their consumption changes throughout the day, week, or month, and compare it to previous periods.

Smart meters can also help extend the life of solar panels by optimizing their performance and detecting any faults or problems (Chatterji, 2020). They can monitor how much electricity the panels generate and feed into the grid and receive payment for it. They also facilitate the transition to dynamic tariffs that offer lower prices when demand is low or supply is high, such as when the sun is shining. Smart meters help balance the supply and demand of electricity, reduce greenhouse gas emissions, and support the integration of renewable energy sources. They can also improve grid reliability and security by enabling remote control and communication between different devices and operators.

According to the European Commission, smart meters are a critical component of future energy management and offer potential benefits such as cost savings, energy efficiency and environmental sustainability. However, using these meters to sell surplus electricity requires the involvement of a broker. Brokers bring power producers and buyers together in the spot market, where prices fluctuate based on supply and demand. By using a broker, generators can sell their surplus power directly on the spot market, resulting in better profitability and a longer life for solar panels.

3.3 Integration of Virtual Power Plants (VPPs)

A virtual power plant (VPP) is a network of individual distributed energy resources, such as photovoltaics and batteries, located in different places. By joining together to form a VPP, these systems can then participate in electricity trading and provide grid services and grid support (Yang et. al., 2021).

They join with other solar system owners to form a VPP that functions like a single large power plant. They can then sell their excess electricity to the grid or other consumers through a broker or platform, or offer services such as frequency control, load tracking, or operating reserve. These services help maintain the balance and stability of the grid, especially when there are fluctuations in supply and demand due to weather conditions or other factors (Parida et. al., 2011). Joining a VPP can increase revenue from solar panels, reduce dependence on the grid, and contribute to a cleaner and more resilient energy system. A VPP extends the life of solar panels by enabling more efficient and profitable energy management while helping to integrate more renewable energy sources into the grid. This is a win-win situation for solar panel owners and the environment (Wang et. al., 2021).

3.4 Facilitating Direct Marketing Strategies

Smart meters and virtual power plants are not the end of the incentivizing strategies. There is another concept that can make solar panels even more profitable and attractive: direct marketing. Direct marketing is a model that allows solar panel owners to sell excess electricity directly to the end consumers, without going through intermediaries such as utilities or retailers (Solar-Log, n.d.). A broker or a platform can be used to connect with potential buyers who are looking for clean and affordable energy. In addition, a PV owner can also set desired prices and terms for electricity, based on market conditions and preferences. With direct marketing, a PV owner can have more control and flexibility over solar energy production and consumption. PV owners can also have more transparency and efficiency in transactions, as can avoid paying fees or commissions to middlemen.

3.5 Policy Recommendations and Outlook

To implement our suggested solutions, a set of policy recommendations has been formulated in a paper to provide concrete steps for implementation, not only for the German government but also for other governments that want to follow this business model. In the following, we address the most important set of instruments in the paper.

First, governments should consider providing financial incentives and subsidies to PV operators for the installation of smart meters. These incentives can help offset the costs associated with upgrading to smart metering technology, making it more accessible and attractive for operators to adopt.
Furthermore, governments should develop a centralized and user-friendly platform that streamlines the process of joining and participating in Virtual Power Plants (VPPs). This platform should provide comprehensive information, facilitate communication between participants, and offer advanced management software for optimizing energy flows and providing real-time feedback.

In addition, governments, in collaboration with industry stakeholders, should launch awareness campaigns to educate PV operators about the benefits of retaining solar panels. These campaigns should highlight the potential for increased revenues, reduced reliance on the grid, and the environmental benefits of prolonging the lifespan of solar panels.
Organizing educational workshops and training programs can also help PV operators gain a deeper understanding of smart meters, VPPs, and direct marketing. These workshops should provide hands-on training, practical demonstrations, and real-life case studies to showcase the positive impact of these concepts on energy management and profitability.
Governments should encourage collaboration and partnerships between PV operators, technology providers, financial institutions, and energy market players. By fostering collaborations, and knowledge sharing, stakeholders can collectively develop innovative business models, financing options, and market mechanisms that support the long-term use of solar panels.

Moreover, governments should review and update the existing regulatory frameworks to align with the changing energy landscape and promote the retention of solar panels. This mainly involves revisiting the EEG regulations to introduce alternative mechanisms that ensure fair compensation for PV operators beyond the initial funding period.
Finally, governments should allocate resources for research and development initiatives focused on advancing energy management technologies and practices. Funding research projects can lead to the development of new tools, algorithms, and optimization techniques that enhance the performance, efficiency, and lifespan of solar panels.

By implementing these key actions, governments can create an enabling and supportive environment to encourage PV operators to embrace smart meters, participate in VPPs, and engage in direct marketing. These measures will not only benefit PV operators by increasing their profitability and reducing financial barriers but also contribute to the overall transition toward a sustainable, decentralized, and resilient energy system.

3.6 Stakeholder Analysis and Outreach

To ensure the successful implementation of the policy recommendations, it is crucial to foster stakeholder support and communicate effectively with the different actors. We have identified several key stakeholders that are very important to consider in our approach.

First, PV operators are identified as key stakeholders who need to be made aware of the benefits of extended use of solar panels, including the potential for increased revenue, cost savings, and environmental impact. They should also be aware of the benefits of upgrading to smart meters, connecting to virtual power plants, and direct marketing. Outreach should highlight the financial incentives, technological advances, and regulatory support available to them.

Regulators and policymakers also play a vital role – as illustrated within our challenge - in creating an enabling and incentivizing environment for the prolonged use of solar panels. They should be aware of the policy recommendations presented in this report and understand how these interventions can support the renewable energy transition, promote grid stability, and foster economic growth. Clear communication of the potential benefits, implementation strategies, and necessary regulatory adjustments is essential to gain their support.

Finally, financial institutions such as BayernLB must recognize the investment potential that lies in supporting the long-term use of solar modules and ultimately their recyclability. By financing such energy projects, they can increase the incentive for the expansion of clean energy and the use of renewable energy, thereby increasing the potential returns on investments in infrastructure upgrades, the development of VPP platforms, and the financing of energy projects. Outreach efforts should highlight the market opportunities, risk mitigation strategies, and innovative financing mechanisms available to financial institutions.

By addressing the needs of every stakeholder group and tailoring the outreach accordingly, we as a society can build a shared understanding, foster collaboration, and ensure the support necessary for implementing the policy recommendations.

4. Conclusion

In this report, we presented the challenges associated with the limited lifespan of solar panels under the German Renewable Energy Sources Act (EEG) and provided a set of policy recommendations to tackle them. By incentivizing the prolonged use of solar panels and promoting measures such as smart meters, virtual power plants, and market access, we can create a sustainable energy future.

The policy recommendations focus on implementing tariff structures, promoting smart meters and virtual power plants, enhancing market access, and fostering collaboration among stakeholders. These measures aim to incentivize the prolonged use of solar panels and create a sustainable and resilient energy future. Effective outreach efforts and stakeholder engagement will be crucial in implementing these recommendations. By raising awareness about the benefits of prolonged solar panel use and providing targeted information, we can garner support and drive successful implementation.

In conclusion, it is essential to act quickly and implement these recommendations to shape a brighter and more sustainable future.

6 References

Aboagye, B., Gyamfi, S., Ofosu, E. A., Djordjevic, S. (2021). Degradation analysis of installed solar photovoltaic (PV) modules under outdoor conditions in Ghana. Energy Reports. https://doi.org/10.1016/j.egyr.2021.10.046.

Bloch, L., Holweger, J., Ballif, C. et al. (2019). Impact of advanced electricity tariff structures on the optimal design, operation and profitability of a grid-connected PV system with energy storage. Energy Inform 2. https://doi.org/10.1186/s42162-019-0085-z

Bundesministeriums der Justiz & Bundesamts für Justiz. (2023). EEG 2023 - Gesetz für den Ausbau erneuerbarer Energien. https://www.gesetze-im-internet.de/eeg_2014/EEG_2023.pdf

Chatterji, E. (2020). Smart Meter Data to Optimize Roof-top Solar and Battery Size. IEEE Electric Power and Energy Conference (EPEC), Edmonton, AB, Canada. 10.1109/EPEC48502.2020.9320026.

European Commission. (n.d.). Smart grids and meters: Smart grids and smart meters enable better management of energy networks and more efficient consumption. https://energy.ec.europa.eu/topics/markets-and-consumers/smart-grids-and-meters_en

Frischknecht, R., Heath, G., Raugei, H., et. al. (2016). Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity. 3rd edition. IEA PVPS Task 12. International Energy Agency Photovoltaic Power Systems Programme.

Haegel, N. M. et al. (2017). Terawatt-scale photovoltaics: Trajectories and challenges. Science356. DOI:10.1126/science.aal1288

Parida, B., Iniyan, S., Goic, R. (2011). A review of solar photovoltaic Technologies. Renewable and Sustainable Energy Reviews. https://doi.org/10.1016/j.rser.2010.11.032.

Solar-Log. (n.d.) Market PV Energy: Direct- Simple – Fast. utions/direct-marketing

Wang, Y., Gao, W., Qian, F., Li, Y., (2021). Evaluation of economic benefits of virtual power plant between demand and plant sides based on cooperative game theory, Energy Conversion and Management. https://doi.org/10.1016/j.enconman.2021.114180.

Wittenberg, I., & Matthies, E. (2016). Solar policy and practice in Germany: How do residential households with solar panels use electricity?. *Energy Research & Social Science*.

Xu, Y., Li, J., Tan, Q., Peters, A. L., Yang, C. (2018). Global status of recycling waste solar panels: A review. Waste Management. https://doi.org/10.1016/j.wasman.2018.01.036.

Yang, Q., Wang, H., Wang, T., Zhang, S., Wu, X., Wang, H. (2021). Blockchain-based decentralized energy management platform for residential distributed energy resources in a virtual power plant, Applied Energy. https://doi.org/10.1016/j.apenergy.2021.117026