

Sustainable Business Models for Photovoltaic (PV) Systems in Developing Countries

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Abstract. This paper reviews sustainable business models for Photovoltaic (PV) Systems in developing countries. Firstly, it examines the global adoption of energy business models, noting the shift from customer-owned to community-shared initiatives in developing nations and the prominence of the virtual net metering and store-on grid schemes. Secondly, it identifies barriers to distributed energy solutions, exploring the evolution of PV business models and the advantages of community-shared models over other alternatives. Lastly, it investigates the deployment of customer-sited PV systems in Germany, Japan, and the USA, highlighting distinctive business models that have catalysed PV adoption. The review offers insights for decision-makers and solar firms navigating the PV sector in developing countries.

1 Introduction

The global energy landscape has been undergoing a transformative shift, with the emergence of distributed power generation systems. These systems, characterized by their scalability, proximity to demand, and cost-effectiveness, have been pivotal in steering the transition from centralized to more hybrid energy networks. Such a transition is driven by the compelling advantages of distributed power generation, including its alignment with

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sustainable development factors like environmental conservation, techno-economic feasibility, and socio-political considerations. Renewable energy, particularly from sources like the sun and wind, stands at the forefront of these efforts, offering a sustainable alternative to conventional energy sources.

However, the journey towards a renewable energy-driven future is not without its challenges. Despite the global push for renewable energy, stakeholders face significant hurdles, especially when designing energy business models. One of the most debated issues in this realm is the choice of billing schemes. The literature underscores the need for energy business models that not only support sustainable development goals, such as ensuring access to clean and affordable energy, but also enhance other socio-economic benefits. Yet, a comprehensive evaluation of the successes, failures, and unique attributes of these models on a global scale remains conspicuously absent.

The solar photovoltaic (PV) industry, in particular, has witnessed remarkable growth and evolution. However, despite its potential, the PV market faces deceleration in major markets due to policy shifts and regulatory ambiguities. Innovative business models, such as third-party-owned (TPO) and community-shared (CS) models, have emerged as potential solutions to address these challenges. These models, by offering diverse solutions like Power Purchase Agreements, leases, and virtual net-metering, underscore the importance of innovation in the PV market. Yet, the adoption and success of these models are intricately tied to the socio-political context of different countries, necessitating a deeper understanding of their workings across varied national settings.

This review aims to bridge this knowledge gap by examining three pivotal areas: the existing billing schemes and their challenges, the potential of the store-on grid scheme as an alternative, and the strategies that developing countries can adopt for successful energy business model implementation. By drawing insights from the PV systems deployment in countries like Germany, Japan, and the US, this study seeks to offer a comprehensive perspective on the evolution of PV business models, their contextual dependencies, and the strategies to overcome barriers to their adoption.

2 Review and discussion

In recent years, the energy sector has witnessed a surge in interest towards renewable energy, particularly in the context of distributed power generation. As countries grapple with the challenges of climate change and the need for sustainable energy solutions, understanding the intricacies of energy business models becomes paramount. In this backdrop, a comprehensive study conducted by Mukisa et al. (2022) delved deep into the operationalisation of customer-side renewable energy business initiatives [1]. Their research aimed to understand the dynamics, challenges, and opportunities associated with these initiatives, especially in the context of billing schemes. By meticulously examining various models and their practical implications, Mukisa et al. (2022) provided valuable insights that are instrumental for policymakers, stakeholders, and researchers alike. The findings from their study, as listed in the sub-sections below, are particularly enlightening as they address the first pivotal area of our review, focusing on the existing billing schemes and their challenges. This area, often overlooked, holds significant implications for the successful adoption and scalability of renewable energy initiatives, especially in developing countries.

Key findings of the study are as below [4-8]:

- Billing Schemes and Their Challenges
 - Developed countries have successfully implemented the FiT scheme, while many developing countries have struggled due to factors like low rates and unfavourable institutional designs.
 - Developed countries often combined FiT schemes with other incentives, such as soft loans with low interest rates, which was not common in developing countries.
 - Virtual net metering is the most commonly used scheme for community-shared energy business initiatives in developed countries. However, it faces opposition, especially from utility operators.
 - The store-on grid (SoG) scheme addresses many shortcomings of existing billing schemes and offers potential as an alternative. It defines revenue streams for stakeholders and provides methods to evaluate compensation rates.
- Recommendations for Developing Countries
 - The SoG scheme is recommended for community-shared energy business initiatives, especially for rooftop-mounted solar PV technology.
 - Industrial sectors, with their large rooftop spaces, are ideal for solar PV installations, avoiding the need for land acquisition.
 - Policy recommendations mainly target developing countries due to their under-electrification and frequent grid outages. However, some recommendations are also applicable to developed countries.
- Policy Implications and Future Directions
 - Policymakers should consider redirecting subsidies from fossil-fuel-based electricity generation towards solar PV technology deployment.
 - Soft loans with low interest rates, awareness campaigns, and international funding sources can further support the adoption of renewable energy business models.

In the light of our review article, it becomes evident that the challenges and opportunities associated with billing schemes are central to the adoption and success of renewable energy business models. Mukisa et al.(2022)'s study provides a comprehensive understanding of these challenges, especially in the context of developing countries. Their recommendations, particularly regarding the SoG scheme and the potential of the industrial sector, offer valuable insights for policymakers and stakeholders aiming to foster renewable energy adoption. As we delve deeper into the intricacies of sustainable business models for Photovoltaic (PV) Systems in developing countries, the findings from this study serve as a foundational reference, highlighting the complexities and potential solutions in the realm of billing schemes and policy interventions.

Another study by Horváth et al. (2018) delves into the barriers affecting the deployment of renewable energy technologies and the basic photovoltaic (PV) business models [2]. Through a comprehensive literature review, the study identifies and contrasts the value propositions, creation, delivery, and capture mechanisms of various PV business models. In the evolving landscape of renewable energy, the quest for efficient and sustainable billing schemes remains paramount. The store-on grid scheme emerges as a promising

alternative, aiming to address the challenges faced by existing billing systems and to optimise the benefits of renewable energy deployment. Horváth et al. (2018) provide a comprehensive analysis of various photovoltaic (PV) business models, shedding light on their value propositions and operational mechanisms. Their findings listed below, especially in the context of the store-on grid scheme, offer valuable insights into the potential pathways for enhancing the adoption and efficiency of renewable energy initiatives.

Key Findings of the study are as below [9-12]:

- **PV Business Models Overview**
 - **Host-owned Model:** Offers turn-key solutions with independence from utilities, but may have high upfront costs. The model focuses on system purchase, installation, and operation.
 - **Third-party-owned Model:** Provides a lower and predictable electricity price with no upfront costs. It operates through lease and power purchase agreements (PPAs) and assumes no operational and maintenance responsibilities.
 - **Community-shared Model:** Allows users to benefit from green energy without hosting the PV system. It offers decreased financial barriers and costs, and focuses on subscriber management and the sale of solar bonds.
- **Value Propositions:**
 - All three models offer reduced energy bills, but the savings vary.
 - Investment viability depends on financing solutions and available support.
- **Benefits of Community-shared Model:**
 - Offers potential economies of scale.
 - Utilizes the latest technology and optimizes solar installation areas for maximum efficiency.
 - Provides utilities with an opportunity to innovate and increase competitiveness.
- **Challenges and Solutions:**
 - Regulatory and institutional issues can restrict the spread of renewables.
 - Existing business models provide limited solutions to these challenges.
 - Policymakers need to establish comprehensive regulatory and incentive schemes.
 - Localized financing mechanisms and innovative business models can boost the use of renewables.
- **Future Prospects:**
 - The community-owned model can offer significant benefits in various areas.
 - Trends like digitization and the sharing economy are expected to further support the development of the community-owned model.

The findings from Horváth et al. (2018) serve as a complementary lens through which we can examine the potential of the store-on grid scheme. While the study highlights the distinct advantages and challenges of various PV business models, it also underscores the need for innovative solutions to overcome regulatory and institutional barriers. The store-on grid scheme, with its focus on guaranteeing profitability for all stakeholders and addressing the shortcomings of existing billing systems, could be the missing piece in this complex puzzle. By integrating the insights from this study with the store-on grid scheme,

policymakers and industry stakeholders may find a more holistic and effective approach to accelerate the transition to renewable energy.

In another study by Strupeit et al. (2016), the intricate dynamics of photovoltaic (PV) business models across different countries were explored [3]. The research delved into how various firms, with their unique business models, navigated the challenges and barriers to PV adoption, ultimately contributing to its diffusion in mainstream markets. The study also emphasized the significant role of context in shaping these business models [13-19].

Table 1. Comparative Analysis of PV Business Models Across the US, Japan, and Germany

Aspect	US	Japan	Germany
Value Proposition	Easy PV adoption with immediate savings	Low transaction costs for PV adoption	Green financial investment with competitive returns for property owners
Key Features	- No upfront costs - Immediate electricity bill savings	- Turnkey product solutions - Advisory support	- Feed-in tariffs - Low-risk financial investment
Risk Management	Transferred to commercial entities via warranties and insurance	Trust built through established construction sector firms	Reliance on established firms and certification schemes
Financial Model Base	Third-party ownership (TPO) model	Direct purchase with supportive services	Feed-in tariff (FiT) scheme

Following this comparative analysis, it becomes evident that while each country has its unique approach to promoting PV systems, there are shared challenges and strategies. The business models, though diverse, all aim to simplify the adoption process for consumers, reduce associated risks, and offer financial incentives or savings. For developing countries, insights from these established models can be invaluable. By adapting and integrating elements from these successful strategies, developing nations can tailor energy business models that address their unique challenges, such as limited access to capital or higher transaction costs. Furthermore, fostering collaborations with established firms and leveraging supportive policy frameworks can accelerate the adoption of renewable energy solutions. In the context of our review article, understanding these models provides a comprehensive view of global strategies in PV deployment, underscoring the importance of tailoring PV business models to the specific needs, challenges, and opportunities of each region, ensuring that the adoption of renewable energy sources is both efficient and effective.

3 Future scope of research

As the global energy landscape evolves, there's a pressing need to delve deeper into renewable energy business models, especially in the context of developing nations. While the current research provides a comprehensive understanding of existing models, there are

several avenues that future studies can explore to further enhance the efficiency, adaptability, and sustainability of these models.

- **Alternative Billing Schemes:** With the Store-on Grid scheme showing promise, research could focus on its long-term viability, scalability, and adaptability in various socio-economic contexts.
- **Integration of Emerging Technologies:** The role of technologies like blockchain, artificial intelligence, and the Internet of Things (IoT) in streamlining and enhancing renewable energy business models.
- **Consumer Behaviour Analysis:** Deep dives into the evolving preferences, behaviours, and acceptance levels of consumers towards different renewable energy business models, especially in developing countries.
- **Policy Evolution:** As policies play a pivotal role in the success of these models, future research can focus on the dynamic interplay between policy frameworks, market forces, and renewable energy adoption.
- **Decentralised Energy Systems:** Investigate the potential and challenges of microgrids and community-based energy systems in rural and urban settings.
- **Financial Mechanisms:** Explore innovative financing and investment models that can boost the adoption of renewable energy systems, especially in regions with limited access to capital.

4 Knowledge gaps

While the current review provides a robust understanding of the renewable energy business models, there are certain areas where knowledge remains sparse. Identifying these gaps is crucial, not just for academic pursuits, but to ensure that policymakers, business leaders, and stakeholders have a holistic view of the challenges and opportunities in this domain.

- **Granular Data on Developing Countries:** While we have insights from developed nations, there's a lack of detailed, region-specific data from many developing countries, which can provide nuanced insights into local challenges and opportunities.
- **Long-term Impact Analysis:** Most studies focus on the immediate or short-term impacts of renewable energy business models. There's a gap in understanding the long-term socio-economic and environmental impacts.
- **Interplay of Multiple Renewable Sources:** While individual renewable sources like solar and wind have been studied, there's limited knowledge on models that integrate multiple renewable sources.
- **Cultural and Social Influences:** The role of cultural, social, and behavioural factors in the acceptance and success of renewable energy business models remains under-researched.

- **Supply Chain Challenges:** While the end consumer models are discussed, there's limited understanding of the challenges and opportunities in the renewable energy supply chain, from raw material sourcing to end-product delivery.
- **Impact of Global Events:** The influence of global events, such as pandemics or economic downturns, on the adaptability and resilience of renewable energy business models is an area that warrants deeper exploration.

By addressing these future research avenues and knowledge gaps, the global community can be better equipped to harness the full potential of renewable energy, driving a sustainable and inclusive energy future.

5 Conclusion

The transition to renewable energy is not just a technological shift but also a transformation in how energy is produced, distributed, and consumed. Through our review of the three pivotal studies, we've gleaned insights into the challenges and opportunities presented by various renewable energy business models. These findings not only reinforce the assertions made in our abstract but also provide a comprehensive understanding of the current landscape and the path forward.

- **Diverse Billing Schemes:** Mukisa et al. (2022) highlighted the challenges and potential of various billing schemes, with the Store-on Grid scheme emerging as a promising alternative, especially for developing countries.
- **Role of Business Models:** Horváth et al. (2018) emphasised the significance of business models in overcoming barriers to renewable energy adoption. Their study underscored the importance of aligning business strategies with local contexts and consumer preferences.
- **Contextual Dependence:** Strupeit et al. (2016) demonstrated that renewable energy business models are deeply influenced by their national and regional contexts. This includes factors like policy frameworks, consumer behaviours, and market dynamics.
- **Consumer-Centric Approaches:** Across all studies, there's a consistent emphasis on the importance of reducing complexity for consumers, whether it's through financial models, technological solutions, or policy interventions.
- **Policy's Pivotal Role:** The success of renewable energy business models is intricately linked to supportive policy frameworks. Whether it's feed-in tariffs, tax incentives, or regulatory structures, policies play a crucial role in shaping the renewable energy landscape.
- **Potential for Developing Countries:** While developed countries have made significant strides in renewable energy adoption, there's immense potential for developing countries to leapfrog traditional energy models. By adopting innovative business models and learning from global best practices, these nations can drive a sustainable energy revolution.

In essence, the journey towards a renewable energy future is multifaceted, requiring the confluence of technology, policy, business strategies, and consumer behaviours. As posited in our abstract, the evolution of renewable energy business models is not just an academic pursuit but a roadmap for a sustainable, inclusive, and resilient energy future.

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