

**Empowering Progress: The Intersection of Policy, Technology, and Community in U.S.
Solar Adoption**

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On my honor as a University Student, I have neither given nor received unauthorized aid on this
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Introduction

The shift towards renewable energy in the United States marks a significant chapter in the nation's journey toward sustainability, with solar power at the forefront of this transformation. The exploration of solar energy's role in this transition not only sheds light on technological advancements but also reflects a broader societal shift toward sustainable living. This pivotal change is underpinned by a confluence of strategic public policies, technological advancements, and a strong wave of grassroots advocacy, collectively steering the country toward a greener future. However, it is imperative to also consider counterarguments and challenges, such as environmental concerns related to the production and disposal of solar panels and the intermittency of solar power, which pose questions about the feasibility and sustainability of this transition. As solar energy becomes increasingly integral to America's energy landscape, understanding the multifaceted drivers behind its adoption is crucial.

The rise of solar power from a costly alternative to a leading renewable energy source encapsulates a story of innovation, policy foresight, and community engagement. Central to this narrative are initiatives such as the Federal Investment Tax Credit (ITC) and state-specific programs like Connecticut's Residential Solar Investment Program, which have played significant roles in democratizing solar energy access. This evolution of solar power in the U.S. is not solely a tale of technological breakthroughs but also a reflection of shifting societal values towards environmental stewardship and sustainability. For those newly acquainted with the energy sector, appreciating the intricate relationship between governmental policy, technological progress, and public sentiment is essential for a comprehensive understanding of solar energy's ascendance.

This research paper contends that the widespread adoption of solar panels in the United States has been substantially influenced by a combination of targeted public policies, technological innovations, and grassroots advocacy efforts. It also acknowledges the persistent challenge of socioeconomic disparities in solar access. Through an extensive literature review, this study scrutinizes the impact of pivotal policy mechanisms and state-level incentives in nurturing the solar sector's growth. A mixed-methods analysis, informed by the Social Construction of Technology (SCOT) framework, assesses how public policies have facilitated solar panel adoption, drawing on policy documents, stakeholder publications, and public surveys.

The investigation uncovers a dynamic interplay between policy interventions, technological advancements, and advocacy in promoting solar energy, alongside insights into the socioeconomic hurdles that hinder equitable access. In conclusion, the paper emphasizes that while public policies have been crucial in advancing solar energy, addressing remaining barriers is imperative for fostering an equitable energy transition. This thesis underlines the need for policy frameworks that not only champion solar energy but also prioritize inclusivity and equity, ensuring the solar transition benefits all segments of American society, paving the way for a truly sustainable and inclusive energy future.

Literature Review

The rapid expansion of the U.S. solar industry, significantly influenced by the implementation of the Investment Tax Credit (ITC) in 2006, exemplifies the critical role of governmental incentives in renewable energy adoption. This policy initiative, providing a 30% tax credit for solar installations, has not only facilitated a dramatic increase in solar capacity but also underscored the importance of sustained federal and state support for green energy solutions (SEIA, 2023). Extensions of the ITC, including its inclusion in the Inflation Reduction Act of

2022, further emphasize the government's commitment to fostering the growth of the solar sector. Similarly, state-level programs like Connecticut's Residential Solar Investment Program (RSIP) have played a pivotal role in enhancing solar adoption across various demographics, thereby addressing broader patterns of policy impact and mitigating energy injustice (Konzen, 2024).

In parallel with policy advancements, significant technological innovations and cost reductions have been instrumental in lowering the barriers to solar power adoption. The period from 2010 to 2020 saw notable decreases in the cost of residential, commercial rooftop, and utility-scale PV systems, primarily due to advancements in photovoltaic (PV) cell technology and the achievement of economies of scale in manufacturing (NREL, 2021). These developments have not only made solar power more accessible to a wider audience but also highlighted the essential role of technological innovation in driving the solar industry forward. As PV module efficiency continues to increase, solar installations become more cost-effective, further enhancing the competitiveness of solar energy as a sustainable alternative to traditional fossil fuels.

Amidst these technological and policy advancements, public support and advocacy for solar energy have emerged as significant drivers of the technology's adoption. Surveys conducted by the Pew Research Center (2023) reveal that a majority of Americans support international efforts to combat climate change and prioritize the development of alternative energy sources, such as solar, over the expansion of fossil fuel energy production. However, the readiness for a complete transition away from fossil fuels presents a nuanced challenge, reflecting the complex landscape of public sentiment towards renewable energy. The role of grassroots advocacy, illustrated by initiatives like Solar United Neighbors (Solar United Neighbors, n.d.), is crucial in

mobilizing community support and influencing policy decisions. Such collective actions underscore the transformative potential of community engagement in shaping the solar energy landscape and driving forward the agenda for a sustainable energy future.

SCOT Framework

To comprehensively understand the multifaceted nature of solar energy adoption, this study employs the Social Construction of Technology (SCOT) framework. SCOT offers a lens to examine the intricate relationship between technological innovations and the social dynamics that shape their development and acceptance. This framework posits that technological outcomes are not merely the result of engineering or economic factors but are deeply embedded in social processes (Klein & Kleinman, 2002).

SCOT emphasizes the importance of interpretive flexibility, suggesting that different social groups may have varied interpretations of the same technology, influenced by their unique contexts and needs (Klein & Kleinman, 2002). This concept is particularly relevant to solar panel adoption, where stakeholders such as policymakers, consumers, and environmental activists interact with and shape the technology's trajectory. By applying SCOT, this study aims to uncover how these diverse interpretations and engagements contribute to the broader adoption and integration of solar technology into society.

Furthermore, SCOT's notions of technological frames and closure provide valuable tools for analyzing how consensus is reached among different actors, leading to the stabilization of solar technology's role and meaning within the energy landscape (Klein & Kleinman, 2002). It is through this theoretical lens that the current research seeks to explore the dynamic interplay between policy, technology, and community in driving solar energy adoption, offering a nuanced

analysis that goes beyond traditional deterministic models of technological change. In applying SCOT to the study of solar energy adoption, I aim to highlight the complexity of technological adoption as a social phenomenon, underscoring the critical role of societal values, political action, and community engagement in shaping technological pathways.

Methods

In exploring the promotion of affordable solar panels and the corresponding public policies in the United States in the 21st century, this study adopts a mixed-methods research design, integrating both qualitative and quantitative analyses to capture a multifaceted view of policy impacts on solar energy adoption at both state and national levels. This methodology allows for a nuanced understanding of the complex interplay between policy, technology, and social acceptance in the context of solar energy adoption. The approach is designed to uncover the mechanisms through which policies influence the adoption of solar technologies, drawing on a diverse range of data sources to ensure a comprehensive understanding of the policy landscape and its effectiveness.

Primary sources of data include a detailed examination of policy documents complemented by publications from key stakeholders in the solar energy sector, such as the Solar Energy Industries Association (SEIA) and the National Renewable Energy Laboratory (NREL). These documents provide insights into the evolution of the policy environment and market dynamics affecting solar panel adoption. The analysis is further informed by the SCOT framework, guiding my examination of how various stakeholder perspectives and societal values influence policy effectiveness and technological adoption in the solar sector. In parallel, public opinion on solar energy, as documented in surveys by organizations like the Pew Research

Center, offers a lens into societal attitudes and support for renewable energy initiatives, adding depth to the analysis of policy effectiveness (SEIA, 2023; NREL, 2021; Pew Research Center, 2023).

Guiding the analytical lens of this study is the Social Construction of Technology (SCOT) framework, which emphasizes the interpretive flexibility of solar technology across different social groups, including policymakers, industry players, and the public (Klein & Kleinman, 2002). By applying SCOT, the research aims to dissect how various interpretations and technological frames influence the promotion and adoption of solar panels. This framework facilitates a refined exploration of the socio-technical negotiations that underpin policy development, revealing the roles of advocacy, legislative action, and public perception in shaping the solar energy landscape.

This research approach involves a detailed examination of qualitative data from essential policy frameworks and contributions from significant stakeholders, focusing on uncovering predominant strategies and legislative actions that bolster solar energy. Parallel to this, an analysis of quantitative data concerning solar installations and financial incentives assesses the effects of policy measures on the rates of solar adoption. This blend of qualitative and quantitative insights, interpreted through the SCOT framework, seeks to reveal the complex interplay between technological innovation, societal values, and policy development driving the adoption of solar energy in the U.S., presenting a holistic view of the factors contributing to the growth of the solar industry over the past two decades.

Analysis

The landscape of residential solar adoption in the United States has been profoundly shaped by an array of state and federal-level solar incentive programs, alongside the strategic evolution of policies such as the Federal Investment Tax Credit (ITC) and Net Energy Metering (NEM) policies. These programs' success underscores the critical role of policy in catalyzing technological adoption and public engagement with renewable energy sources. The ITC, by providing a 30% tax credit for solar system installations, has been instrumental in spurring a substantial increase in solar capacity, illustrating the fundamental role of fiscal incentives in advancing the solar industry (SEIA, 2023). Moreover, localized incentive programs, as evidenced by Connecticut's success in boosting solar installations, highlight the potency of tailored approaches in enhancing solar energy adoption within specific regions (Konzen et al., 2024). The refinement of policies such as NEM, reflects the dynamic political environment and the need to adjust strategies in response to the solar market's growth and the broader societal call for renewable energy (Stokes et al., 2024). The inclusion of community solar projects represents an innovative model to broaden energy access, especially for those without suitable rooftops, showcasing the diverse strategies at play across different government levels to cultivate a sustainable and renewable energy future. These concerted efforts underscore the complex interplay between technological innovation, policy development, and community engagement in shaping the U.S.'s solar energy landscape.

Building upon the foundational support provided by state and federal incentive programs, the momentum towards widespread solar energy adoption has been further propelled by remarkable technological advancements and notable reductions in cost. Documented by the National Renewable Energy Laboratory, the solar industry has seen substantial cost reductions

across residential, commercial rooftop, and utility-scale photovoltaic (PV) systems between 2010 and 2020, with prices decreasing by 64%, 69%, and 82% respectively (NREL, 2021). These significant price reductions, driven by advancements in module efficiency and reductions in hardware costs, have played a crucial role in enhancing the economic viability of solar energy (O'Shaughnessy et al., 2019). Coupled with policies aimed at fostering renewable energy use, these technological improvements have not only made solar power more accessible but have also broadened its appeal among American households. This evolution reflects a concerted effort to harness technology and policy in tandem, moving solar energy from a niche option to a mainstream energy solution.

Public support and grassroots advocacy have become instrumental in accelerating the transition towards solar energy, reflecting a societal shift towards sustainability and clean energy solutions. According to a 2023 Pew Research Center survey, a staggering 74% of Americans advocate for the U.S. to participate in global climate change mitigation efforts, with two-thirds expressing a preference for the development of renewable energy sources over traditional fossil fuels (Pew Research Center, 2023). Additionally, the Solar Energy Industries Association (SEIA, 2023) highlights the growing trend of community solar projects, which have successfully broadened the demographic reach of solar energy, ensuring access for households across different income levels. These initiatives illustrate how advocacy can democratize access to solar energy, responding to the public's growing demand for renewables (SEIA, 2023). Together, these trends highlight how public opinion and advocacy drive solar energy adoption, aligning societal values with policy and market developments.

While the adoption of solar energy presents a sustainable alternative to fossil fuels, concerns regarding the environmental impacts of manufacturing solar panels have emerged as a

notable counterargument. The production of first-generation crystalline silicon solar cells, for example, is energy-intensive and involves the use of toxic chemicals, raising significant environmental concerns (Rabaia et al., 2021). However, the solar industry's commitment to innovation and sustainability is evident in the development of more eco-friendly manufacturing processes and the exploration of second and third-generation solar technologies. These newer technologies, such as thin-film solar cells and organic photovoltaics, not only require less energy for production but also minimize the use of environmentally detrimental materials (Rabaia et al., 2021). Additionally, initiatives led by organizations within the solar sector, such as SEIA, are enhancing recycling efforts to address end-of-life panel disposal, aiming to recover and reuse valuable materials. (SEIA, 2023). These advancements and efforts highlight the solar industry's proactive approach to mitigating its environmental footprint, ensuring solar energy remains a vital, sustainable option for the future. However, the debate extends beyond panel production, touching upon challenges associated with energy intermittency and the lifecycle management of energy storage systems, illustrating the multifaceted nature of adopting solar energy.

The reliability of solar energy is a topic of significant debate, particularly regarding its intermittency. The variability of solar energy production, influenced by weather conditions and the diurnal cycle, poses significant challenges to its reliability and consistent supply to the grid. Critics often cite this intermittency as a major limitation, arguing that the dependency on solar energy could compromise grid stability during periods of low sunlight (Suberu et al., 2014). However, from the SCOT perspective, this critique presents an opportunity for socio-technical negotiation among various stakeholders, including technology developers, policymakers, and the public. The development and integration of better energy storage systems (ESS) like batteries are

seen as vital solutions to manage this intermittency, albeit with significant initial investments (Suberu et al., 2014).

Alongside intermittency, the environmental impact of energy storage solutions and solar panel end-of-life management further complicates the transition to solar energy. The use of toxic materials in batteries, coupled with challenges in recycling solar panels, raises questions about the long-term sustainability of solar energy solutions (Suberu et al., 2014; Chowdhury et al., 2020). Through the SCOT lens, these concerns invite a closer examination of the technological frames held by environmental groups, industry stakeholders, and regulatory bodies. Initiatives aimed at developing more eco-friendly manufacturing processes, enhancing the efficiency of recycling methods, and establishing comprehensive regulatory frameworks for solar panel disposal reflect a negotiation process aimed at aligning solar technology with broader environmental and social goals (Chowdhury et al., 2020). This negotiation underscores SCOT's concept of closure, as society seeks to stabilize the meaning and role of solar energy in a way that addresses both its potential and its challenges.

Despite the growth in solar energy, socioeconomic disparities in adoption persist, highlighting the need for more equitable policy frameworks. Research indicates a pronounced gap in solar adoption rates between higher-income households and those in lower-income communities, with the latter often facing substantial barriers to access (Konzen et al., 2024). This disparity is not just about economic barriers but also involves the availability of information and the structural complexities of implementing solar solutions in varied living situations.

In response to these challenges, the concept of renewable energy communities has gained attention as a transformative solution. Renewable energy communities, characterized by collective action and shared ownership of renewable resources, significantly contribute to

democratizing energy access and addressing socioeconomic disparities (Ahmed et al., 2024). Community solar projects, as an example of such communities, offer a promising model by allowing individuals without direct roof access to participate in and benefit from solar energy, illustrating a step toward mitigating these disparities (Konzen et al., 2024; Stokes et al., 2024). These initiatives exemplify the SCOT framework's principle of technology as a social construct, where community engagement and shared values shape the adoption and implementation of solar technologies (Klein & Kleinman, 2002). Despite their success, broader policy interventions are required to ensure these solutions reach all segments of the population effectively (Konzen et al., 2024). Implementing targeted initiatives that focus on reducing installation costs, simplifying access to information, and enhancing community engagement are critical steps toward achieving a more equitable energy transition (Konzen et al., 2024; Stokes et al., 2024).

Furthermore, the application of the SCOT framework reveals the importance of interpretive flexibility in understanding the dynamics of solar energy adoption (Klein & Kleinman, 2002). This concept underscores the variability in how different social groups perceive and interact with solar technology. For instance, while policymakers might view solar panels as essential tools for achieving energy independence and reducing carbon emissions, consumers may see them as a means to lower energy costs or contribute to environmental sustainability. This diversity in interpretation highlights the necessity of a nuanced approach to policy-making and technology development, one that considers the perspectives and motivations of all relevant social groups (Klein & Kleinman, 2002). This insight from the SCOT framework accentuates the critical need for policies and technologies that resonate across different societal segments, facilitating a more inclusive energy transition.

Conclusion

This research journey into the adoption of solar energy in the United States has illuminated the intricate interplay between policy frameworks, technological advancements, and grassroots advocacy efforts. What began as an exploration of solar panels' technical and economic aspects evolved into a comprehensive understanding of the broader socio-political landscape that shapes renewable energy adoption. It has become evident that the path to widespread solar energy utilization is multifaceted, requiring not only continuous technological innovation but also supportive policies and active community engagement. The integration of these dimensions is crucial for advancing solar energy as a sustainable and accessible option for all, highlighting the need for a holistic approach to energy transition.

The implications of this study extend to various stakeholders within the energy landscape. Policymakers are called upon to craft and implement solar energy incentives that prioritize effectiveness and inclusivity, ensuring that the benefits of renewable energy reach across societal divides. Industry stakeholders, from renewable energy companies to technology developers, are encouraged to innovate in ways that lower costs and reduce environmental impacts, broadening the appeal and accessibility of solar technology. Moreover, the power of community advocacy in influencing energy policy and promoting a culture of sustainability underscores the vital role of public engagement in driving the renewable energy agenda forward.

Looking beyond our borders, the actions of Germany and China offer valuable lessons for the United States in integrating solar power into our energy portfolios. Germany's Renewable Energy Sources Act has set ambitious targets for renewable energy, significantly advancing solar energy's role in the national grid (IEA, 2023). Similarly, China's investment in solar research and development positions it as a leader in solar energy production, with national strategies focused

on R&D leading to advancements that reduce costs and improve efficiency (Burrows, 2021). These examples highlight the potential of targeted policy measures and strategic R&D investments in promoting solar energy adoption, suggesting pathways for the U.S. to enhance its solar energy initiatives (IEA, 2023; Burrows, 2021).

Future research in this field presents numerous opportunities for further exploration. Investigating the long-term impacts of specific policies on solar adoption rates, the development of more sustainable materials for solar panel production, and the effectiveness of community solar projects in democratizing energy access are all areas ripe for inquiry. Addressing these questions could provide valuable insights for refining strategies and policies, ensuring that the transition to renewable energy is both equitable and comprehensive.

In conclusion, this study underscores the complex yet hopeful narrative of solar energy adoption in the United States. The journey toward a sustainable energy future is a collective endeavor that necessitates the alignment of technological, policy, and societal forces. This exploration has not only highlighted the successes achieved but also underscored the ongoing challenges that must be addressed. Among these, the integration of energy storage solutions to manage solar power's intermittency and the development of recycling methods for solar panel end-of-life represent critical areas for future innovation. By recognizing the complex nature of technology as shaped by social processes, as highlighted by SCOT, this research advocates for an integrated approach that embraces the diversity of interpretations and technological frames across different stakeholder groups (Klein & Kleinman, 2002). By embracing an integrated approach that values inclusivity and innovation, we can ensure that solar energy plays a pivotal role in achieving environmental sustainability and energy equity for future generations.

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