

Developing Solar Thermal Power Plant to Improve Energy Governance

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Abstract: This paper explores the development of solar thermal power plants as a viable solution to enhance energy governance in the context of sustainable energy systems. With the increasing global demand for clean and renewable energy sources, solar thermal technology has emerged as a promising alternative that can significantly contribute to reducing greenhouse gas emissions while ensuring energy security. The paper outlines the potential benefits of solar thermal power plants, including their ability to provide base load power, their scalability, and their compatibility with existing energy infrastructure. Additionally, it examines the critical role of effective energy governance in facilitating the successful implementation and operation of solar thermal projects. This includes the establishment of clear regulatory frameworks, stakeholder engagement, and the promotion of public-private partnerships. The paper presented best practices and key challenges encountered in the development of solar thermal power plants, emphasizing the importance of integrated planning and comprehensive policy approaches. Ultimately, this research aims to contribute to the discourse on energy governance by providing insights into how solar thermal power can be leveraged to foster sustainable energy transitions and enhance energy governance frameworks.

Keywords: Solar thermal power, Energy governance, Renewable energy, Greenhouse gas emissions, Sustainable energy systems.

1. Introduction

The urgent need for clean and renewable energy solutions has never been more pressing, as the world grapples with the dual challenges of climate change and energy security [1]. As global populations continue to rise and industrial activities increase, the demand for energy is projected to escalate significantly [2]. In this context, transitioning from fossil fuels to sustainable energy sources is critical for reducing greenhouse gas emissions and mitigating the impact of climate change [3]. Among the various renewable energy technologies available, solar thermal power has emerged as a promising alternative that offers not only environmental benefits but also strategic advantages for energy governance [4].

Solar thermal power plants capture and convert sunlight into thermal energy, which can be used to generate electricity or provide heating [5]. This technology stands out due to its capability to deliver baseload power—energy that is consistently available regardless of weather conditions—making it compatible with existing energy infrastructure and able to support grid stability [6]. Furthermore, solar thermal systems are scalable, allowing for flexibility in meeting the diverse energy needs of different regions, from small-scale facilities to large, utility-scale plants [7]. However, the successful development and operation of solar thermal power plants hinge on the effectiveness of energy governance [8]. Establishing clear regulatory frameworks is essential to provide certainty for investors and operators.

Moreover, stakeholder engagement is crucial for aligning interests and building public support for renewable energy initiatives. Public-private partnerships play a pivotal role in leveraging resources, expertise, and innovation necessary for advancing solar thermal projects [9].

This paper seeks to explore these dynamics by examining the development of solar thermal power plants as a viable solution to enhance energy governance within sustainable energy systems. This study aims to contribute to the discourse on energy governance by offering insights into how solar thermal power can not only foster sustainable energy transitions but also strengthen governance frameworks that are critical for the future of energy systems worldwide. Ultimately, this research underscores the importance of an integrated approach to energy planning, policy-making, and governance in harnessing the full potential of solar thermal power in pursuit of a sustainable energy future.

2. Solar Thermal Power Plant

Clean energy refers to forms of energy that have little or no negative impact on the environment. Renewable energy sources, such as wind, solar, hydroelectric, and geothermal, are replenished naturally and are considered sustainable in that their use does not deplete finite resources. The shift towards these sources is driven by policy changes, technological advancements, and increasing awareness of climate challenges. Solar thermal technology captures sunlight and converts it into heat, which can then be used to generate electricity or provide direct heating. Different systems, such as concentrating solar power (CSP) plants and flat-plate collectors, exemplify this technology. Across the globe, there is a growing recognition of the environmental impacts of fossil fuels, particularly in terms of greenhouse gas emissions that contribute to climate change. As populations expand and economies develop, the demand for energy is projected to rise. This trend necessitates exploring new energy solutions that are sustainable and environmentally friendly. Solar thermal technology has gained attention as a viable solution to meet energy demands. This is largely due to its ability to provide substantial energy generation while minimizing environmental impacts compared to traditional fossil fuel sources.

One of the primary advantages of solar thermal technology is its potential to significantly reduce greenhouse gas emissions. Unlike fossil fuels, solar energy is clean—when it is produced, it does not emit carbon dioxide or other harmful pollutants that contribute to climate change. As nations aim to fulfill international climate commitments like the Paris Agreement, adopting solar thermal technology can play a crucial role in transitioning away from carbon-intensive energy sources and lowering overall emissions. On the other hand, energy security refers to the reliable availability of energy resources at an affordable price. Ensuring energy security involves reducing dependency on imported fuels, diversifying energy sources, and enhancing resilience against disruptions. Solar thermal technology contributes to energy security in several ways. First, by harnessing abundant sunlight, countries can reduce their reliance on imported fossil fuels, which are subject to market volatility and geopolitical tensions. Secondly, solar thermal plants can provide stable and consistent power supply (base load power) that enhances the overall reliability of the energy grid. In these days, a significant trend is observed in the energy sector, emphasizing the growing global shift toward clean and renewable resources due to rising energy demands and environmental concerns. Solar thermal technology is highlighted as a viable and effective alternative that not only helps reduce greenhouse gas emissions but also contributes to national and global energy security.

The potential benefits of solar thermal power plants, focusing on the three aspects mentioned: their ability to provide base load power, their scalability, and their compatibility with existing energy infrastructure. Solar thermal power plants can provide base load power positions them as a reliable energy source capable of supporting grid stability. Scalability allows to be tailored to meet diverse energy needs in various locations, enhancing their effectiveness. Also, the solar thermal power plants have enough compatibility with existing energy infrastructure facilitates integration into current systems, supporting a smoother transition to renewable energy. Together, these attributes make solar thermal power a compelling option for addressing the challenges of modern energy demands and environmental sustainability.

Unlike photovoltaic (PV) solar systems, which only produce electricity during sunny conditions, solar thermal power plants can generate heat and electricity consistently. This is achieved by storing thermal energy for use even when the sun is not shining. Many solar thermal facilities use thermal energy storage systems, such as molten salt, which can hold heat generated during the day and release it during the night or during periods of high demand. This ability allows them to act as base load providers, contributing stability to the energy supply. By providing reliable and controllable power output, solar thermal plants help balance supply and demand on the electrical grid. This reduces the reliance on fossil fuel plants to meet base load requirements and diminishes the risks associated with fluctuations in power supply.

Another benefit of the solar power plants is scalability. Scalability refers to the capability of a system to grow and adapt in size or capacity according to demand. This flexibility is crucial for meeting varying energy needs across different regions and contexts. Solar thermal power plants can be designed in a modular fashion, meaning they can be built in smaller units or larger complexes, depending on the energy requirements of a specific location. This allows for efficient scaling up or down as needed, addressing local energy demands without overinvesting in infrastructure. Solar thermal technology can be implemented in various settings—from small-scale community systems to large utility-scale plants. This adaptability makes it suitable for both rural areas lacking access to centralized power and urban settings where energy consumption may be higher.

Compatibility with existing energy infrastructure is another benefit of the solar thermal power plants. Solar thermal power plants can be connected to existing energy grids, making it easier for them to contribute to the energy supply without requiring extensive modifications to the current infrastructure. This is particularly important for regions looking to transition to renewable energy sources while maximizing their existing investments in energy generation. Many solar thermal plants can work in conjunction with other energy sources, such as natural gas or biomass. This hybrid approach can enhance reliability and reduce emissions by allowing the plant to use conventional fuel sources when solar energy is insufficient, thereby ensuring continuous power supply. In regions where solar thermal plants are installed, they can often utilize existing transmission lines and energy storage systems, facilitating a more integrated and efficient energy system. This compatibility also implies that investment in solar thermal does not necessitate the complete overhaul of existing energy infrastructure, which can be cost-prohibitive.

Generally, the development of solar thermal power plants can significantly benefit from best practices that include effective stakeholder engagement, innovative financing, optimized technologies, robust regulations, and infrastructure investments. However, challenges such as high costs, technical issues, regulatory hurdles, land use conflicts, and energy storage concerns must be addressed. Emphasizing integrated planning and comprehensive policy approaches is crucial; these strategies help align projects with broader energy objectives, promote sustainability, and improve project viability, ultimately leading to more successful solar thermal initiatives.

3. Energy Governance

Energy governance is a multifaceted concept that involves the coordination of policies, institutions, and stakeholder engagement to ensure that energy systems are managed effectively and equitably. It plays a critical role in shaping how energy resources are developed and utilized, guiding the transition to more sustainable energy systems while balancing economic, social, and environmental considerations. Through effective energy governance, countries and organizations can work toward achieving energy security, sustainability, and social welfare. Effective energy governance is crucial for the successful implementation and operation of solar thermal projects. Establishing clear regulatory frameworks creates a stable environment for investment, while stakeholder engagement ensures that diverse perspectives are considered and local communities are involved in the decision-making process. Promoting public-private partnerships can facilitate resource mobilization, risk sharing, and innovation, ultimately leading to more successful and sustainable solar thermal initiatives. Together, these elements of governance help create a conducive atmosphere that supports the growth of renewable energy technologies, contributing to broader sustainability goals and energy transitions.

The critical role of effective energy governance in the context of solar thermal projects, emphasizing the components: the establishment of clear regulatory frameworks, stakeholder engagement, and the promotion of public-private partnerships. As mentioned establishment of clear regulatory frameworks is a critical role of effective energy governance in the context of solar thermal projects. A regulatory framework encompasses laws, guidelines, and policies that govern the development and operation of energy projects. Clear regulations provide certainty and stability for investors and developers, which is essential for attracting financing and resources to solar thermal projects. Consistency and predictability in regulatory frameworks are crucial for long-term planning. Sudden changes in regulations can deter investment and disrupt project implementation, while stable policies foster confidence among stakeholders. In this regard, regulatory frameworks must include streamlined permitting processes that define the step-by-step requirements for project approval. This can reduce the time and costs associated with project initiation. Also, regulations should outline performance standards for technology efficiency, emissions, and safety, ensuring that solar thermal plants operate within environmental and operational guidelines that protect public interests. Effective governance includes policies that facilitate the integration of renewable energy onto the grid, such as rules for access to transmission networks and grid management practices that prioritize renewable sources, too.

Stakeholder engagement is known as another critical role of effective energy governance in the context of solar thermal projects. Stakeholders include all individuals and groups who have an interest or investment in the solar thermal project. This can encompass government agencies, local communities, environmental groups, investors, and utility companies. Public forums, consultations, and informational sessions can inform community members about the potential impacts and benefits of solar thermal projects, ensuring that their voices are heard in the governance process. Engaging stakeholders early in the project development process

can help build trust and reduce opposition. Effective communication about the benefits and impacts of solar thermal projects is essential to gain local support. By involving a wide range of stakeholders, project developers can incorporate diverse perspectives and concerns into project planning. This may lead to better decision-making and outcomes that are aligned with community needs and environmental considerations. Proactive engagement can identify potential conflicts and help resolve issues before they escalate. Meaningful dialogue can lead to compromises that benefit all parties involved.

Finally, Promotion of Public-Private Partnerships (PPPs) is another critical role of effective energy governance in the context of solar thermal projects. Public-private partnerships are collaborative agreements between public sector entities (like government agencies) and private sector companies (like energy developers). These partnerships leverage the strengths and resources of both sectors to achieve shared goals. Many successful solar thermal projects worldwide have been achieved through partnerships between governments and private entities. By aligning incentives and responsibilities, these partnerships can lead to the successful deployment of solar thermal technology. PPPs can facilitate access to funding and investment that might not be available through public funding alone. Private investors often bring capital and expertise that can enhance project viability. By pooling resources and sharing responsibilities, risks associated with the development, operation, and maintenance of solar thermal projects can be distributed between public and private partners, improving project resilience. Private companies may introduce innovative technologies and management practices that enhance project performance and cost-effectiveness.

4. Good Energy Governance with Developing Solar Thermal Power Plant

Developing good energy governance through the establishment of solar thermal power plants involves creating a robust framework that supports effective decision-making, transparency, accountability, and stakeholder engagement. In other words, developing good energy governance with solar thermal power plants requires a multifaceted approach that prioritizes policy alignment, stakeholder engagement, transparency, and accountability. By implementing these strategies, stakeholders can create an enabling environment that supports the successful development and operation of solar thermal projects while promoting sustainable energy practices. Ultimately, good governance will enhance the effectiveness of solar thermal initiatives, contributing to a more sustainable and resilient energy future.

There are several strategies to achieve good energy governance in this context including:

1. Establishing Comprehensive Policy Frameworks

- **Clear Regulatory Guidelines:** Develop comprehensive policies and regulations specifically designed for solar thermal technologies. This includes permitting processes, safety standards, and environmental regulations that facilitate project development while protecting public interests.
- **Incentive Structures:** Implement financial incentives, such as tax credits, grants, or feed-in tariffs, to encourage investment in solar thermal projects. These incentives can lower barriers to entry and stimulate private sector participation.

2. Enhancing Stakeholder Engagement

- **Community Involvement:** Engage local communities in the planning and decision-making processes for solar thermal projects. This ensures that local concerns and needs are addressed, fostering public support and acceptance.
- **Multi-Stakeholder Platforms:** Create forums that bring together government agencies, private sector players, non-governmental organizations, and community representatives to discuss challenges, share best practices, and collaborate on solutions.

3. Promoting Transparency and Accountability

- **Transparent Processes:** Implement measures to ensure transparency in the approval processes for solar thermal projects, including public access to information regarding project plans, impacts, and financial aspects.
- **Performance Reporting:** Establish metrics to regularly assess the performance of solar thermal power plants, and require periodic reporting to stakeholders. This can include environmental impact assessments, energy output data, and economic benefits.

4. Investing in Capacity Building and Education

V. Innovative technologies and plants in energy science

- **Training Programs:** Develop training initiatives for policymakers, energy managers, and local communities to enhance knowledge about solar thermal technologies, governance practices, and renewable energy systems.
- **Public Awareness Campaigns:** Run campaigns to inform the public about the benefits of solar thermal energy and the importance of governance in energy transitions, fostering broader support for renewable energy initiatives.

5. Facilitating Public-Private Partnerships (PPPs)

- **Encourage Collaboration:** Foster partnerships between government entities and private companies to share resources, expertise, and risk. These collaborations can facilitate the financing, development, and management of solar thermal projects.
- **Innovative Financing Models:** Explore financing mechanisms such as green bonds or crowdfunding to attract diverse funding sources for solar thermal initiatives, ensuring that investments align with governance objectives.

6. Implementing Integrated Planning

- **Consistency with Energy Policy:** Ensure that solar thermal development aligns with broader national or regional energy policies, including goals for renewable energy targets, carbon emissions reduction, and energy security.
- **Holistic Energy Planning:** Integrate solar thermal initiatives into regional and local energy plans, considering factors such as resource availability, infrastructure needs, and potential impacts on existing energy systems.

7. Monitoring and Evaluation

- **Effectiveness Assessment:** Develop a framework for monitoring and evaluating the impact of solar thermal power plants on energy governance, including social, economic, and environmental outcomes.
- **Adjusting Policies Based on Data:** Utilize data gathered through monitoring to inform policy adjustments, improve project implementation, and enhance the overall governance framework.

8. Aligning with Global Standards and Initiatives

- **International Collaboration:** Engage with international organizations and frameworks that promote good governance in energy sectors, such as the International Renewable Energy Agency (IRENA) or adherence to the Sustainable Development Goals (SDGs).
- **Best Practices:** Learn from other countries and regions that have successfully integrated solar thermal power into their energy systems, adopting best practices that contribute to effective governance.

Generally, the contributing to the discourse on energy governance by providing insights into the role of solar thermal power is crucial for fostering sustainable energy transitions. By showcasing how solar thermal technology can be effectively utilized within energy governance frameworks, stakeholders can enhance their understanding of renewable energy's potential and integrate it into broader sustainability goals. This not only supports the shift toward cleaner energy systems but also helps create resilient, equitable, and effective energy governance structures that can better adapt to the challenges of the future.

5. Recommended Practices

There are some recommended policies to support the development of solar thermal power plants, enhance energy governance, and promote sustainable energy systems:

1. Regulatory Frameworks

- **Streamlined Permitting Processes:** Implement regulations that establish clear and efficient permitting processes for solar thermal projects, reducing bureaucratic hurdles and expediting approvals while ensuring environmental protections.
- **Standardization of Technical Guidelines:** Develop standardized codes and technical guidelines for the design, construction, and operation of solar thermal power plants to enhance safety, reliability, and integration with existing infrastructure.

2. Incentive Programs

- **Financial Incentives:** Create financial support programs, such as tax credits, grants, or subsidies, to lower the upfront costs for solar thermal projects, making them more accessible for developers and investors.
- **Feed-in Tariffs or Power Purchase Agreements (PPAs):** Establish long-term feed-in tariffs or PPAs to provide guaranteed pricing for energy generated by solar thermal plants, encouraging investment and ensuring predictable revenue streams.

3. Stakeholder Engagement Policies

- **Public Consultation Processes:** Mandate public consultation requirements for solar thermal projects to ensure community input and address potential concerns, boosting local support and social acceptance.
- **Multi-Stakeholder Partnerships:** Promote the formation of collaborative partnerships between government, industry, and civil society to foster dialogue, share best practices, and enhance governance in solar thermal project implementation.

4. Investment in Research and Development

- **Funding for Innovation:** Increase government funding and support for research and development of advanced solar thermal technologies, including energy storage solutions and improved efficiency systems.
- **Technology Transfer Initiatives:** Facilitate technology transfer programs that allow emerging economies to access advanced solar thermal technologies and expertise, promoting global cooperation in renewable energy development.

5. Integrated Energy Planning

- **Comprehensive Energy Policies:** Develop integrated energy policies that consider solar thermal energy contributions within broader energy systems, balancing renewable energy sources with energy storage, demand-side management, and conventional energy generation.
- **Long-Term Energy Roadmaps:** Create long-term energy roadmaps that set forth clear targets for the deployment of solar thermal energy, ensuring alignment with national energy security and climate goals.

6. Monitoring and Evaluation Frameworks

- **Performance Monitoring Systems:** Implement comprehensive monitoring and reporting systems for solar thermal projects to evaluate their performance, energy output, environmental impacts, and alignment with policy objectives.
- **Benchmarking and Best Practices:** Establish benchmarking metrics to assess solar thermal projects against best practices and facilitate continuous improvement and knowledge sharing among stakeholders.

7. Education and Capacity Building

- **Training Programs for Workforce Development:** Establish training programs aimed at developing skills in solar thermal technologies for engineers, technicians, and project managers, ensuring a skilled workforce to support industry growth.
- **Public Awareness Campaigns:** Launch educational initiatives to inform the public and key stakeholders about the benefits and opportunities of solar thermal power, enhancing understanding and support for renewable energy policies.

8. Aligning with International Standards

- **Global Standards Adoption:** Adopt international standards and best practices related to solar thermal energy development and governance, ensuring that local policies are consistent with global frameworks for sustainable development.
- **Participation in International Initiatives:** Encourage participation in global partnerships and initiatives focused on renewable energy development to share knowledge, resources, and strategies for effective governance and implementation.

By implementing these recommended policies, governments and stakeholders can create a conducive environment for the development of solar thermal power plants. These policies will not only facilitate the successful integration of solar thermal energy into existing energy systems but will also enhance energy governance, transparency, and public trust—ultimately contributing to a sustainable energy transition and addressing climate change challenges.

6. Conclusion

This paper underscores the critical role that solar thermal power plants can play in enhancing energy governance within sustainable energy systems. As global demand for clean and renewable energy rises, solar thermal technology presents a viable solution that not only addresses the urgency of reducing greenhouse gas emissions but also strengthens energy security through its capability to provide base load power and scalability. The integration of effective energy governance practices is essential for the successful implementation and operation of solar thermal projects. This includes the establishment of transparent regulatory frameworks, active stakeholder engagement, and the encouragement of public-private partnerships that align diverse interests. The findings highlight that there are significant prospects associated with solar thermal power. This research contributes to the broader discourse on energy governance, suggesting that solar thermal power not only offers a pathway towards sustainable energy transitions but also reinforces the governance structures needed to support such advancements. Ultimately, embracing solar thermal technology can assist countries in achieving their energy and climate goals, facilitating a more sustainable and resilient energy future.

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References

- [1] B.K. Sovacool, The best of both worlds: Environmental federalism and the need for federal action on renewable energy and climate change, *Stan. Envtl. LJ*, 27 (2008) 397.
- [2] J.P. Dorian, H.T. Franssen, D.R. Simbeck, Global challenges in energy, *Energy policy*, 34 (2006) 1984-1991.
- [3] M.J.B. Kabeyi, O.A. Olanrewaju, Sustainable energy transition for renewable and low carbon grid electricity generation and supply, *Frontiers in Energy research*, 9 (2022) 743114.
- [4] R. Loni, E.A. Asli-Areh, B. Ghobadian, A. Kasaeian, S. Gorjian, G. Najafi, E. Bellos, Research and review study of solar dish concentrators with different nanofluids and different shapes of cavity receiver: Experimental tests, *Renewable Energy*, 145 (2020) 783-804.
- [5] R. Loni, E.A. Asli-Ardeh, B. Ghobadian, E. Bellos, W.G. Le Roux, Numerical comparison of a solar dish concentrator with different cavity receivers and working fluids, *Journal of Cleaner Production*, 198 (2018) 1013-1030.
- [6] R. Loni, A. Kasaeian, E.A. Asli-Ardeh, B. Ghobadian, S. Gorjian, Experimental and numerical study on dish concentrator with cubical and cylindrical cavity receivers using thermal oil, *Energy*, 154 (2018) 168-181.
- [7] R. Loni, B. Ghobadian, A. Kasaeian, M. Akhlaghi, E. Bellos, G. Najafi, Sensitivity analysis of parabolic trough concentrator using rectangular cavity receiver, *Applied Thermal Engineering*, 169 (2020) 114948.
- [8] T. Güney, Solar energy, governance and CO₂ emissions, *Renewable Energy*, 184 (2022) 791-798.
- [9] T. Van de Graaf, J. Colgan, Global energy governance: a review and research agenda, *Palgrave Communications*, 2 (2016) 1-12.