

Developing Solar Cavity receivers to Improve Energy Governance

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Abstract: This paper explores the development of solar cavity receivers as a pivotal technology in enhancing energy governance. Solar cavity receivers, which harness concentrated solar power (CSP) to achieve high thermal efficiencies, present a promising solution to the challenges of sustainable energy production. By integrating advanced materials and innovative design principles, this research aims to optimize the performance of solar cavity receivers, thereby increasing their viability for large-scale energy applications. The study examines the implications of improved energy governance through the adoption of solar cavity receivers, focusing on their potential to reduce reliance on fossil fuels, lower greenhouse gas emissions, and promote energy equity. Furthermore, the paper discusses policy frameworks and governance strategies necessary to facilitate the widespread implementation of this technology. Ultimately, the findings underscore the importance of solar cavity receivers in the transition towards a more sustainable and resilient energy future.

Keywords: Solar Cavity Receivers, Concentrated Solar Power (CSP), Energy Governance, Sustainable Energy Production, Policy Frameworks.

1. Introduction

As the world grapples with the pressing challenges of climate change, energy security, and the need for sustainable development, the transition from fossil fuel-based energy systems to renewable energy sources has become imperative [1]. The energy sector is at a crossroads, where innovative technologies must be harnessed to meet the growing demand for clean, reliable, and affordable energy [2]. Among the various renewable energy technologies, solar energy has emerged as a frontrunner due to its vast potential and versatility [3]. Solar energy systems, particularly concentrated solar power (CSP), offer a promising pathway to harness the sun's abundant energy, converting it into usable thermal energy for electricity generation and other applications [4].

Solar cavity receivers represent a significant advancement in CSP technology, designed to capture and concentrate solar radiation effectively [5]. These receivers utilize a reflective cavity to focus sunlight onto a working fluid, achieving high thermal efficiencies that can surpass traditional solar thermal systems [6]. The ability to operate at elevated temperatures not only enhances energy conversion efficiency but also expands the range of applications for solar energy, making it suitable for industrial processes, heating, and electricity generation on a large scale. As such, solar cavity receivers are positioned as a pivotal technology in the quest for sustainable energy solutions [7].

This paper aims to explore the development and optimization of solar cavity receivers, emphasizing their role in enhancing energy governance. Energy governance encompasses the policies, regulations, and institutional frameworks that guide energy production, distribution, and consumption [8]. By integrating advanced materials and innovative design principles, this research seeks to improve the performance and viability of solar cavity receivers, thereby facilitating their adoption in diverse energy markets. The implications of this technology extend beyond mere efficiency gains; they also encompass broader societal benefits, including the potential to reduce reliance on fossil fuels, lower greenhouse gas emissions, and promote energy equity.

In addition to the technological advancements, this study will address the critical policy frameworks and governance strategies necessary to support the widespread implementation of solar cavity receivers [9]. Effective governance is essential to ensure that the benefits of solar energy are equitably distributed and that barriers to adoption are systematically addressed [10]. By examining the intersection of technology and governance, this paper aims to provide a comprehensive understanding of how solar cavity receivers can contribute to a more sustainable and resilient energy future. Ultimately, the findings of this research underscore the importance of solar cavity receivers not only as a technological innovation but also as a vital component in the transition towards a cleaner, more sustainable energy landscape. By leveraging the potential of solar

cavity receivers, we can pave the way for a future that prioritizes environmental sustainability, energy security, and social equity.

2. Solar Cavity Receivers

Solar cavity receivers are an innovative technology within the realm of concentrated solar power (CSP) systems, designed to efficiently capture and convert solar energy into usable thermal energy. Solar cavity receivers are specialized devices that utilize a reflective cavity to concentrate sunlight onto a working fluid. This technology is a key component of CSP systems, which generate electricity by converting solar energy into thermal energy. The receiver typically consists of a highly reflective inner surface that directs incoming solar radiation towards a focal point where the working fluid is heated. The design minimizes heat loss and maximizes the absorption of solar energy. Common working fluids include water, oil, or molten salts, which are heated to high temperatures. The heated fluid can then be used to produce steam that drives turbines for electricity generation or for direct heating applications.

Solar cavity receivers can operate at significantly higher temperatures compared to traditional solar thermal systems, enhancing their efficiency and expanding their range of applications. The design allows for a high concentration ratio, meaning that a large amount of solar energy can be focused onto a small area, resulting in higher temperatures and more efficient energy conversion. Also, the enclosed cavity design minimizes heat loss to the environment, allowing for better retention of thermal energy. By harnessing solar energy, these systems contribute to the diversification of energy sources, reducing dependence on fossil fuels and enhancing energy security. The use of solar cavity receivers significantly lowers greenhouse gas emissions compared to conventional energy generation methods, making them an essential technology in combating climate change. Solar cavity receivers can be deployed in various configurations, from small-scale installations to large solar power plants, making them adaptable to different energy needs and geographical locations.

While solar cavity receivers offer numerous advantages, there are challenges to their widespread adoption including the capital costs associated with the development and installation of solar cavity receiver systems can be high, which may deter investment. The advanced materials and engineering required for efficient operation necessitate specialized knowledge and expertise. Incorporating solar cavity receivers into existing energy infrastructures may require significant modifications and supportive policies.

Generally, solar cavity receiver harness concentrated solar power to achieve high thermal efficiencies, making them a promising solution to the challenges of sustainable energy production. Their ability to convert solar energy into thermal energy efficiently positions them as a critical technology in the transition towards renewable energy systems. As research and development continue to advance this technology, solar cavity receivers could play a pivotal role in achieving global sustainability goals, reducing environmental impacts, and promoting energy equity.

The optimization of solar cavity receivers through the integration of advanced materials and innovative design principles is crucial for enhancing their performance and increasing their viability for large-scale energy applications. The choice of materials used in solar cavity receivers significantly impacts their efficiency, durability, and overall performance. Materials such as ceramics, advanced composites, and specialized alloys are designed to withstand the high temperatures generated within the receiver. These materials maintain structural integrity and thermal performance, ensuring long-term operation. The use of advanced reflective coatings on the inner surfaces of the cavity enhances the concentration of solar energy. These coatings are engineered to maximize reflectivity while minimizing absorption losses, allowing more sunlight to be directed towards the working fluid. Incorporating materials that can store thermal energy, such as phase change materials (PCMs) or molten salts, allow for better energy management. This enables the system to provide a continuous energy supply even when sunlight is not available, enhancing reliability.

The shape and size of the cavity are optimized to maximize solar concentration and minimize heat loss. Designs that incorporate parabolic or cylindrical geometries can enhance the focusing of sunlight onto the working fluid. Innovative designs that improve heat transfer between the working fluid and the receiver surface can significantly enhance thermal efficiency. This may involve the use of enhanced heat exchangers or optimized flow patterns to ensure uniform heating. Developing modular solar cavity receiver systems allows for scalability and flexibility in deployment. These systems can be easily expanded or adapted to meet varying energy demands, making them suitable for large-scale applications.

By maximizing solar energy capture and minimizing heat losses, optimized solar cavity receivers can achieve higher thermal efficiencies, making them more effective at converting sunlight into usable energy. The use of durable materials and robust designs ensures that solar cavity receivers can operate effectively over extended periods, reducing maintenance needs and downtime. Improved performance and efficiency can lead to lower operational costs and a more favorable return on investment, making solar cavity receivers more attractive for large-scale energy projects. Optimized designs can be scaled up to meet the energy demands of large facilities, such as solar power plants, industrial processes, and district heating systems. High-performance solar cavity receivers can be integrated into existing energy grids, providing a reliable source of renewable energy that complements other energy sources. As countries and regions strive to transition to renewable energy sources, the enhanced performance and reliability of solar cavity receivers position them as a key technology in achieving sustainability goals.

Generally, the integration of advanced materials and innovative design principles is essential for optimizing the performance of solar cavity receivers. These enhancements lead to increased thermal efficiency, reliability, and cost-effectiveness, making solar cavity receivers a viable solution for large-scale energy applications. As research and development continue to advance this technology, solar cavity receivers are poised to play a significant role in the global transition towards sustainable energy systems.

3. Enhancing Energy Governance with Solar Cavity Receivers

The exploration of solar cavity receivers as a pivotal technology in enhancing energy governance involves several key aspects, including their technological development, operational principles, benefits, challenges, and implications for energy policy and governance. The integration of solar cavity receivers into energy systems has profound implications for energy governance including policy development, regulatory frameworks, and stakeholder engagement. In this regards, policymakers must create supportive frameworks that encourage investment in solar technologies, including incentives, subsidies, and research funding. Establishing regulations that facilitate the deployment of solar cavity receivers while ensuring environmental protection and energy reliability is crucial. Also, engaging various stakeholders, including local communities, industry players, and government entities, is essential for successful implementation and acceptance of solar cavity receiver technologies.

The exploration of solar cavity receivers as a pivotal technology in enhancing energy governance highlights their potential to transform the energy landscape. By addressing the challenges and leveraging the benefits, solar cavity receivers can play a crucial role in achieving sustainable energy goals, reducing environmental impacts, and promoting energy equity. As research and development continue, the integration of this technology into energy governance frameworks will be vital for fostering a resilient and sustainable energy future.

In other words, the examination of the implications of improved energy governance through the adoption of solar cavity receivers reveals significant potential benefits in several key areas: reducing reliance on fossil fuels, lowering greenhouse gas emissions, and promoting energy equity. The adoption of solar cavity receivers can play a crucial role in decreasing dependence on fossil fuels, which are a major contributor to environmental degradation and climate change. Solar cavity receivers harness solar energy, a renewable resource that is abundant and widely available. By integrating this technology into energy systems, countries can diversify their energy portfolios and reduce their reliance on finite fossil fuel resources. Reducing dependence on imported fossil fuels enhances energy security for nations, making them less vulnerable to price fluctuations and geopolitical tensions associated with fossil fuel markets. This shift can lead to greater energy independence and stability. The implementation of solar cavity receivers can serve as a transitional pathway for regions heavily reliant on fossil fuels. By gradually integrating renewable technologies, these regions can move towards a more sustainable energy future while maintaining energy supply.

The environmental benefits of adopting solar cavity receivers are significant, particularly in terms of reducing greenhouse gas emissions. Solar cavity receivers produce energy without emitting greenhouse gases during operation. By replacing fossil fuel-based power generation with solar energy, significant reductions in carbon dioxide (CO₂) and other harmful emissions can be achieved. Lowering greenhouse gas emissions is critical in the fight against climate change. The widespread adoption of solar cavity receivers can contribute to national and global efforts to meet climate targets, such as those outlined in the Paris Agreement. While the manufacturing and installation of solar cavity receivers do involve some emissions, these are generally much

lower than the lifecycle emissions associated with fossil fuel extraction, processing, and combustion. As technology advances, the overall carbon footprint of solar technologies continues to decrease.

The integration of solar cavity receivers can also have profound implications for energy equity, ensuring that the benefits of renewable energy are accessible to all communities. Solar cavity receivers can be deployed in remote and underserved areas, providing access to clean and reliable energy where traditional energy infrastructure may be lacking. This can help bridge the energy access gap and improve the quality of life for marginalized communities. The development and deployment of solar cavity receiver technologies can create jobs in manufacturing, installation, and maintenance. These opportunities can be particularly beneficial in regions transitioning away from fossil fuel industries, providing new pathways for economic development. Effective energy governance involves engaging local communities in the decision-making process regarding energy projects. By involving communities in the planning and implementation of solar cavity receiver systems, energy equity can be promoted, ensuring that local needs and priorities are addressed.

The adoption of solar cavity receivers necessitates a reevaluation of energy governance frameworks to support the transition to renewable energy. Governments must create supportive policies that incentivize the adoption of solar cavity receivers, such as tax credits, grants, and feed-in tariffs. These policies can encourage investment and accelerate the deployment of renewable technologies. Establishing clear regulations that facilitate the integration of solar cavity receivers into existing energy systems is essential. This includes streamlining permitting processes and ensuring grid access for renewable energy sources. Effective energy governance requires collaboration among various stakeholders, including government agencies, private sector actors, and local communities. Building partnerships can enhance knowledge sharing, resource mobilization, and the successful implementation of solar cavity receiver projects. The examination of the implications of improved energy governance through the adoption of solar cavity receivers highlights their potential to significantly reduce reliance on fossil fuels, lower greenhouse gas emissions, and promote energy equity. By addressing these critical areas, solar cavity receivers can contribute to a more sustainable and resilient energy future, aligning with global efforts to combat climate change and ensure equitable access to clean energy for all. As such, the integration of this technology into energy governance frameworks is essential for realizing its full potential and achieving long-term sustainability goals.

4. Policy Frameworks and Governance Strategies

The broad adoption of solar cavity receivers requires robust policy frameworks and governance strategies to address various challenges and promote the growth of this technology. The critical components of these frameworks and strategies include:

1. Supportive Policy Frameworks

For effective implementation of solar cavity receivers, governments must establish policies that foster investment and deployment. Key components include:

- **Incentives and Subsidies:** Financial support mechanisms such as tax credits, grants, and subsidies can substantially decrease the initial costs of solar cavity receiver projects. These incentives enhance the attractiveness of the technology for investors and developers, accelerating its deployment.
- **Feed-in Tariffs and Power Purchase Agreements (PPAs):** The establishment of feed-in tariffs or long-term power purchase agreements can provide fixed prices for electricity generated by solar cavity receivers. This financial stability can encourage investment and ensure the economic viability of projects.
- **Research and Development Funding:** Allocating resources for research and development can stimulate innovation in solar cavity receiver technology, improving efficiency and reducing costs. Supporting partnerships between academia and industry can lead to advancements in materials, design, and integration.

2. Regulatory Frameworks

Developing clear regulatory frameworks is essential for effectively incorporating solar cavity receivers into existing energy systems. Important considerations include:

- **Streamlined Permitting Processes:** Simplifying the permitting process for solar cavity receiver installations can reduce bureaucratic hurdles and expedite project timelines. This may involve creating standardized guidelines and shortening approval periods.

- Grid Access and Interconnection Standards:** Ensuring that solar cavity receivers have access to the energy grid is vital for their success. Regulatory frameworks should specify interconnection standards that enable the efficient integration of renewable energy sources into the grid.

- Environmental and Safety Regulations:** While promoting solar cavity receivers, it is fundamental to adhere to environmental and safety standards. Regulations must ensure that installations do not negatively impact local ecosystems and that safety protocols are strictly followed during construction and operation.

3. Governance Strategies

Effective governance strategies are necessary to coordinate efforts among diverse stakeholders and ensure the successful deployment of solar cavity receivers. Key strategies include:

- Stakeholder Engagement:** Engaging a wide range of stakeholders—including government agencies, industry representatives, local communities, and environmental organizations—is crucial for reaching consensus and addressing concerns. Collaborative decision-making can improve project acceptance and support.

- Capacity Building and Education:** Providing training and educational resources to policymakers, industry professionals, and local communities can enhance understanding of solar cavity receiver technology and its benefits. Capacity-building initiatives empower stakeholders to participate actively in the transition to renewable energy.

- Monitoring and Evaluation:** Implementing systems for monitoring and evaluating the performance of solar cavity receiver projects can yield valuable insights into their effectiveness and impact. This information can inform future policy adjustments and enhance governance strategies.

4. Long-Term Energy Planning

Integrating solar cavity receivers into long-term energy planning is vital for ensuring their sustainability and effectiveness. Key considerations include:

- Integrated Resource Planning:** Energy planners should incorporate solar cavity receivers into a holistic energy strategy that includes various renewable sources, energy efficiency measures, and demand-side management. This integrated approach can optimize resource allocation and strengthen grid stability.

- Climate Action Goals:** Aligning the deployment of solar cavity receivers with national and international climate action commitments can increase their relevance and urgency. Policies should reflect goals to reduce greenhouse gas emissions and promote a low-carbon economy.

5. International Cooperation

In light of the global nature of energy challenges, international cooperation is essential for facilitating the adoption of solar cavity receivers. Key aspects include:

- Knowledge Sharing:** Countries can gain from sharing best practices, research findings, and lessons from successful solar cavity receiver projects. International forums and partnerships can facilitate this exchange of knowledge.

- Technology Transfer:** Supporting technology transfer initiatives can assist developing nations in accessing solar cavity receiver technologies and expertise. This assistance can strengthen worldwide efforts to promote renewable energy and sustainable development.

Generally, the widespread implementation of solar cavity receivers requires comprehensive policy frameworks and governance strategies that address financial, regulatory, and operational challenges. By establishing supportive policies, clear regulations, and effective governance practices, governments can facilitate the adoption of solar cavity receivers, promoting the transition to renewable energy and achieving sustainability objectives. Prioritizing stakeholder engagement, investing in research and development, and fostering international cooperation will be crucial for unlocking the full potential of this promising technology.

5. Conclusion

In conclusion, the exploration of solar cavity receivers as a pivotal technology in enhancing energy governance highlights their significant potential in addressing the pressing challenges of sustainable energy production. This paper has demonstrated that solar cavity receivers, through their ability to harness concentrated solar power (CSP) with high thermal efficiencies, can play a crucial role in the transition towards a cleaner and more sustainable energy landscape. By optimizing their performance through advanced materials and innovative

design principles, these receivers not only improve energy output but also contribute to the broader goals of reducing reliance on fossil fuels and lowering greenhouse gas emissions. The implications of adopting solar cavity receivers extend beyond technological advancements; they also encompass critical aspects of energy governance. By promoting energy equity and ensuring that the benefits of solar energy are accessible to diverse communities, solar cavity receivers can help create a more inclusive energy system. This is particularly important in the context of global efforts to combat climate change and achieve sustainable development goals.

Moreover, the discussion of necessary policy frameworks and governance strategies underscores the importance of a supportive regulatory environment for the successful implementation of solar cavity receivers. Policymakers must prioritize the development of incentives, funding mechanisms, and collaborative initiatives that facilitate the integration of this technology into existing energy systems. By addressing barriers to adoption and fostering innovation, we can accelerate the transition to renewable energy sources and enhance energy security. Ultimately, the findings of this research reinforce the critical role of solar cavity receivers in shaping a sustainable and resilient energy future. As we move forward, it is essential to continue investing in research, development, and policy initiatives that support the deployment of solar cavity receivers and other renewable technologies. By doing so, we can pave the way for a cleaner, more equitable, and sustainable energy landscape that meets the needs of current and future generations, ensuring a healthier planet for all.

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