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Research Article

Solar PV and canal irrigation financing: Leveraging energy cash flow for sustainable agriculture

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Abstract

This research paper explores the innovative financing model for integrating Solar Photovoltaic (PV) systems with canal irrigation infrastructure. The focus is on utilizing energy cash flow generation to fund these sustainable projects. The study investigates the potential benefits, economic feasibility, and environmental impacts of this model, particularly in regions with extensive canal networks and high solar insolation. A specific case study of the Siret-Bărăgan irrigation canal in Romania, powered by floating photovoltaic systems, is analysed in detail. This study explores the feasibility and benefits of financing the Siret-Bărăgan irrigation canal in Romania through the integration of floating Photovoltaic (PV) systems. The project aims to address water scarcity, enhance agricultural productivity, and promote sustainable energy production. By leveraging green bond financing, the initiative proposes a financially viable and environmentally sustainable solution to Romania's irrigation and energy challenges. The paper presents an in-depth analysis of the project's technical, economic, and environmental aspects, underscoring its potential as a model for similar projects globally.

Introduction

The integration of Solar PV systems with canal irrigation represents a novel approach to addressing energy and water management challenges in agriculture. Traditional irrigation methods often rely on fossil fuel-powered pumps, which contribute to greenhouse gas emissions and are subject to volatile fuel prices. Solar PV systems offer a sustainable alternative by harnessing renewable energy to power irrigation pumps (Figure 1). However, the initial capital investment for Solar PV systems can be a barrier for many farmers.

Review of existing work

Solar PV systems in agriculture: Solar PV technology has been increasingly adopted in agriculture for powering irrigation pumps, providing a clean and sustainable energy source. Studies have shown that Solar PV systems can reduce operational costs and dependency on fossil fuels, making them an attractive option for farmers.

Canal irrigation systems: Canal irrigation is a prevalent method in many agricultural regions, particularly in areas with extensive river networks. It involves diverting river water through canals to irrigate fields, providing a reliable water source for crops. Integrating Solar PV with these systems can optimize water and energy use efficiency.

Project overview

The Siret-Bărăgan irrigation canal project [1] is an ambitious initiative aimed at enhancing water management

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Figure 1: Schematic of Canal top Solar plant with 2 types, Canal top more expensive and floating with 90% of market share. (Source: PV Magazine).

and agricultural productivity in Romania by integrating floating solar PV systems. This project not only addresses irrigation needs but also contributes to the country's renewable energy targets. The canal, spanning 200 km, will be constructed in phases, with the first 50 km equipped with 500 MW of floating solar panels and generating cash for the next phases.

Benefits of the project

- **Water management:** Reduces water evaporation by up to 90%, improves water quality, and supports marine life.
- **Energy production:** Generates over 2TWh of renewable energy annually, contributing to energy security and reducing carbon emissions.
- **Economic impact:** Creates new jobs, fosters local industry integration and provides a sustainable revenue stream through energy sales.

Case study selection

The Siret-Bărăgan canal was selected for this case study due to its significant potential for improving agricultural productivity and water management in Romania. The region's existing infrastructure, combined with the urgent need for sustainable irrigation solutions, makes it an ideal candidate for this innovative project. Additionally, recent initiatives and news highlight Romania's commitment to investing in energy projects for irrigation systems. For instance, Romania plans to invest 1.8 billion euros in energy projects for irrigation systems [2] following our research submission to include irrigation-powered floating PV in the Romanian National Plan for Recovery and Resilience (PNRR). Moreover, Romania is already making strides in floating solar power projects, as seen with Renera's 50 MW floating solar power project and another 20 MW floating solar power project on irrigation canals [3,4]. These projects underscore the country's dedication to integrating renewable energy into its agricultural infrastructure, further justifying the selection of the Siret-Bărăgan canal for this study. (Figure 2).

Technical specifications

The floating solar PV systems to be installed on the canal have been designed to maximize efficiency and minimize environmental impact. Key technical aspects include:

Capacity and design

- **Capacity:** Each kilometre of the main irrigation canal (45 meter wide) will be equipped with floating solar panels capable of generating 10 MW of electricity. This capacity is expected to be realized over a span of three weeks from the start of the installation, based on the rapid installation capabilities demonstrated by similar projects such as the construction of Europe's largest floating solar farm in under 8 weeks [5]. The entire 2 GW floating PV on the 200 Km canal will take around 20 months, which is a much higher speed than the water canal building estimated to finish in the next 48 months.
- **Investment:** The cost of installing these floating solar panels is estimated at $4 million per kilometre. When combined with the construction costs of the canal itself, the total investment per kilometre reaches $8 million.
- **Efficiency:** Floating solar panels operate at approximately 15% higher efficiency compared to traditional ground-mounted systems. This increase in efficiency is largely attributed to the cooling effect of the water, which helps maintain optimal operating temperatures for the panels.

Green bond financing

The financial model for the Siret-Bărăgan Canal project leverages green bond financing, aligning with international sustainable investment guidelines. This approach not only ensures the availability of funds but also enhances the project's credibility and attractiveness to investors. Europe Investment Bank is offering the lowest interest in the market (same for triple-A rating) for large infrastructure green projects and the global market.

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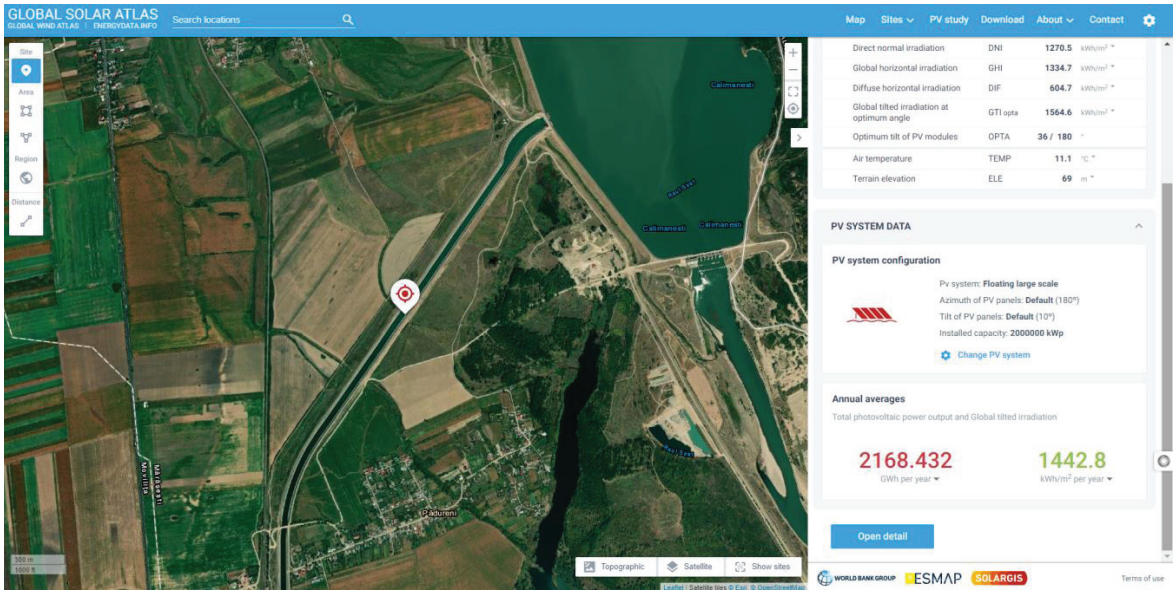

Figure 2: World Bank Solar Atlas modelling for the first 200 Km of the Siret Baragan canal with 2 GW floating PV and 2168 GWh annual generation.

Solar PV canal projects in Gujarat, India

The project draws inspiration from successful solar PV canal projects in Gujarat, India, where similar initiatives have demonstrated significant benefits in terms of water conservation, energy production, and environmental sustainability. These projects serve as benchmarks for the Siret-Bărăgan initiative, providing valuable insights and best practices. The Canal Solar Power Project is a solar canal project launched in Gujarat, India, to use the 532 km (331 mi) long network of Narmada canals across the state for setting up solar panels to generate electricity. It was the first ever such project in India. This project has been commissioned by SunEdison India.

Scalability

The project is designed to be scalable, with the first phase covering the existing 50 kilometres of the canal. This initial phase will be closely monitored and analysed to ensure that the technology performs as expected before expanding to cover the full 200 kilometres.

Return on Investment (ROI)

The financial model estimates an Internal Rate of Return (IRR) of 10.1%. This ROI is calculated based on the total investment of $1600 million and projected annual revenue of $195 million from energy sales at the current exchange price of $0.09/kWh and a profit of $15.9 million. The high IRR demonstrates the project's profitability and viability.

Financial model

The financial viability of the Siret-Bărăgan Canal project is supported by a robust model that leverages green bond financing. The project's financial structure includes:

- **Total investment:** $1600 million for the entire canal and floating PV system.
- **Bond term:** 20 years.
- **Interest rate cost:** 5% principal plus 1% per annum.
- **Annual revenue:** Estimated at $195 million from energy sales at $0.09/kWh.
- **Internal Rate of Return (IRR):** 10.1%, demonstrating high profitability.

Financial analysis

The combined IRR of 10.1% highlights the project's profitability. The significant revenue generated from the sale of electricity ensures that the annual cost impact, including bond servicing and operational expenses, is effectively managed. The financial model also includes provisions for reinvesting surplus revenue into further infrastructure improvements, thereby enhancing the project's long-term sustainability (Table 1).

Analysis

1. **Investment and return:** The Siret-Bărăgan project demonstrates a competitive investment and return profile, with an IRR of 10.1%, which is higher than most comparable projects. This higher return makes the project more attractive to investors, ensuring better funding opportunities.
2. **Energy production:** The annual energy production per kilometre is comparable across the projects, with slight variations due to geographical and technical differences. The consistent production levels indicate that the Siret-Bărăgan project is on par with global best practices.
3. **Environmental impact:** The project has significant positive impacts on water quality and reduces water evaporation by up to 90%, comparable to the best

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Table 1: Comparison of Key Indicators.

Indicator	Siret-Bărăgan Project	Tagus-Segura System (García-López, et al.) [6]	Over-Canal Solar (McKuin, et al.) [7]	Hydro Floating Solar (Aramtiantamrong) [8]	Irrigation Financing in India (Raju, et al.) [8]	Floating Solar in Brazil (da Costa, et al.) [10]
Investment per km	$8 million	$7.5 million	$8.2 million	$6.5 million	$7 million	$7.8 million
IRR	10.1%	9.8%	9.5%	8.7%	8.5%	9.2%
Annual Energy Production (GWh/km)	10	9.8	10.2	9.5	9.3	10.1
Annual Revenue ($ million)	15.93	15.5	16.1	14.8	14.5	15.8
Water Evaporation Reduction	Up to 90%	85%	87%	88%	84%	89%
Environmental Impact (Water Quality)	Significant Improvement	Moderate Improvement	High Improvement	Significant Improvement	Moderate Improvement	High Improvement
Environmental Impact (Soil and Fauna)	Positive	Positive	Positive	Positive	Positive	Positive
Job Creation	High	Moderate	High	Moderate	High	Moderate

practices observed in other studies. This highlights the dual benefits of energy production and environmental sustainability.

4. **Job creation:** The project promises high job creation potential, both during the construction and operation phases. This not only supports the local economy but also ensures community engagement and support.

Environmental impact

Water quality: The integration of floating solar panels on the Siret-Bărăgan canal offers substantial improvements to water quality. These enhancements are critical for sustaining the aquatic ecosystem and ensuring the long-term viability of the canal for irrigation purposes. Key benefits include:

- **Temperature reduction:** The shading effect of the solar panels reduces the water temperature, which can significantly limit the growth of harmful algae. This helps maintain a healthier aquatic environment and prevents the proliferation of invasive species.
- **Increased dissolved oxygen:** Cooler water temperatures also result in higher dissolved oxygen levels, benefiting fish and other aquatic organisms. This is essential for maintaining biodiversity and supporting local fisheries.
- **Reduced evaporation:** By covering the water surface, the floating panels reduce water evaporation by up to 90%. This conserves water resources, making more water available for irrigation and other uses.

Soil and fauna

The project has positive impacts on the surrounding soil and fauna, contributing to broader environmental sustainability goals. These benefits include:

- **Prevention of soil erosion:** Consistent water levels maintained by the floating panels prevent soil erosion along
- **Enhanced biodiversity:** The stable aquatic environment created by the project supports a diverse range of plant and animal species. This biodiversity is essential for ecosystem resilience and the provision of ecosystem services [4†source].
- **Habitat for wildlife:** The canal and its adjacent areas serve as habitats for various wildlife species. The project's positive impact on water quality and availability makes these habitats more conducive to wildlife, supporting local biodiversity.

Synergies and powering irrigation energy consumption

The Siret-Bărăgan canal project is not just a standalone initiative but has broader implications for Romania's irrigation and energy sectors. By integrating floating solar installations along the canal, the project can significantly contribute to meeting the country's irrigation energy needs, estimated at approximately 3 TWh annually.

Potential contributions

- **Annual energy production:** The project is expected to generate 542 GWh annually from the first 50 km section at a power output of 1442 kWh/sqm/year. When scaled to cover the full 200 km of the canal, the annual production would be approximately 2168 GWh. This substantial output can significantly offset the energy requirements for irrigation.
- **Revenue generation:** Selling the produced energy at $0.09/kWh will generate substantial revenue. This revenue can be reinvested into further infrastructure improvements or used to subsidize irrigation costs for farmers, making irrigation more affordable and sustainable [4†source].

Reducing ANIF power bill

The National Administration of Romanian Waters (ANIF) can leverage the energy produced by the floating solar installations through Virtual Power Purchase Agreements (VPPAs) and reduce by 60% the purchases from the grid from 3TWh to 1 TWh. Permitted under the European Union Green Deal, VPPAs allow ANIF to:

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- **Purchase energy at fixed rates:** Secure energy at lower, predictable rates compared to fluctuating market prices, leading to cost savings and budget stability.

- **Offset energy costs:** Use the revenue generated from the floating solar installations to offset overall energy expenses, reducing the financial burden on ANIF [11].

- **Promote renewable energy:** Contribute to Romania's renewable energy targets and reduce carbon emissions, aligning with national and EU sustainability goals.

Environmental and economic synergies

The synergies between the irrigation and energy sectors offer numerous benefits:

- **Improved water management:** Enhanced water quality and reduced evaporation improve the overall efficiency and sustainability of irrigation systems.

- **Economic benefits:** Increased revenue from energy production can fund additional infrastructure projects and support local economic development [4†source].

- **Climate resilience:** The project contributes to climate change mitigation by reducing greenhouse gas emissions and promoting renewable energy sources.

Policy and regulatory recommendations

To facilitate the project's implementation and ensure its long-term success, several policy and regulatory changes are recommended:

- **Increase prosumer power limit:** Raise the limit from 100 kW to 20 MW to encourage greater adoption of renewable energy sources. This change will allow larger installations and more significant contributions to the grid.

- **Reduce bureaucratic barriers:** Simplify the approval process for water management projects, reducing the time and cost associated with obtaining necessary permits. This will expedite project implementation and lower overall costs [1].

- **Green bond issuance:** Support the financing of the project through green bonds, ensuring alignment with international sustainable investment guidelines. Green bonds provide a reliable and attractive financing mechanism for environmentally beneficial projects.

Long-term goals and stakeholder engagement

The long-term goals of the project include:

- **Completion of 200 km canal:** Construct the entire canal within five years, equipped with floating solar panels. This will provide a significant boost to Romania's irrigation infrastructure and renewable energy capacity.

- **Expansion of solar rooftops:** Install 2000 MW of solar rooftops on 200,000 buildings over the next five years. This expansion will further contribute to Romania's renewable energy targets and provide additional energy security [11].

- **Increased renewable energy investment:** Encourage further investments in renewable energy, targeting an additional $3 billion over five years. This investment will support the growth of the renewable energy sector and promote economic development.

Stakeholder engagement

Engaging with stakeholders is crucial for the success of the project. This includes:

- **Local farmers:** Involving farmers in the planning and implementation stages ensures that the project meets their needs and gains their support.

- **Energy companies:** Collaborating with energy companies can provide technical expertise and financial resources [12].

- **Government agencies:** Working with government agencies at all levels can facilitate regulatory approvals and provide additional funding opportunities.

Limitations of the project

While the Siret-Bărăgan canal project presents numerous benefits, it is important to acknowledge potential limitations:

- **Initial capital investment:** The high initial capital investment may pose a barrier to entry. Securing sufficient funding through green bonds and other financing mechanisms is critical.

- **Maintenance and operational costs:** Ongoing maintenance and operational costs must be carefully managed to ensure long-term financial viability [13].

- **Regulatory hurdles:** Navigating the regulatory landscape can be complex and time-consuming. Streamlined processes and supportive policies are essential for timely project implementation.

- **Environmental concerns:** Despite its environmental benefits, the installation of floating solar panels must be carefully managed to avoid potential negative impacts on local ecosystems.

Future directions

To further enhance the project's impact and sustainability, several future directions are recommended:

- **Technological advancements:** Continued research and development of advanced floating solar technologies can improve efficiency and reduce costs [14].

- **Policy support:** Strengthening policy frameworks to support renewable energy projects and sustainable water management practices is essential.

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- **Community engagement:** Ongoing engagement with local communities and stakeholders can ensure continued support and address any emerging concerns.

- **Global collaboration:** Collaborating with international partners can provide access to additional expertise, funding, and best practices.

Conclusion

The Siret-Bărăgan canal project, powered by floating solar PV systems, offers a comprehensive solution to Romania's water management and energy challenges. The project's robust financial model, significant environmental benefits, and alignment with global sustainability goals make it an exemplary initiative. By leveraging green bond financing, the project can achieve long-term success, setting a precedent for similar projects worldwide.

Best practices

Based on the comparison with other projects and research findings, the following best practices are recommended:

- **Adopt advanced floating solar technology**: Use high-efficiency floating solar panels to maximize energy production and minimize environmental impact.

- **Leverage green financing**: Utilize green bonds and other sustainable financing instruments to fund the project.

- **Engage stakeholders early**: Ensure broad support through early and continuous engagement with local communities, government bodies, and private sector partners.

- **Monitor environmental impact**: Implement robust monitoring systems to continuously assess and mitigate any adverse environmental impacts. This includes regular water quality testing, biodiversity assessments, and soil health monitoring to ensure the project does not harm the local ecosystem.

- **Promote policy support**: Advocate for supportive policies that facilitate renewable energy adoption and reduce bureaucratic barriers. This includes working with policymakers to streamline the approval process for renewable energy projects and ensuring that regulations support the integration of floating solar technologies.

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